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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

NEW MEXICO MEETING

AT

ALBUQUERQUE, NEW MEXICO

September 2–5, 1953

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OF THE

AMERICAN PHYSICAL SOCIETY

1953 SEPTEMBER MEETING AT ALBUQUERQUE, NEW MEXICO, SEPTEMBER 2–3–4–5, 1953

THE 1953 September meeting of the American Physical Society—the Summer Meeting in the West—will be held at Albuquerque, New Mexico, on the Campus of the University of New Mexico, on Wednesday, Thursday, Friday, and Saturday, **September 2, 3, 4, and 5, 1953.** We are indebted to Dr. Darol K. Froman and to Dr. Victor H. Regener for much help on the planning of this program. There will be an unusually large number of excellent invited speakers, a panel discussion on artificial mesons to be led by E. Fermi, and a session of our Division of Fluid Dynamics. Excursions to various places of scientific and other interest will be announced. There will be a public lecture by E. Fermi, and a banquet. Although the meetings are to be held on the campus of the University of New Mexico, it is hoped that the other important institutions and laboratories of the region will feel that this is their meeting. The University of New Mexico will provide an unusually efficient and attractive setting for these meetings.

The Washington Bulletin has given all of the information regarding **reservations.** Albuquerque can be reached by TWA from the East or West, and by Continental Air Lines from the North or South. It can be reached by car on U. S. Highway 66 from the East or West, and U. S. Highway 85 from the North or South.

The **registration desk** will be set up in the lobby of the Student Union building. Members and guests are asked to register and to pay a **registration fee** of one dollar. There will be a bulletin board for messages.

On Wednesday morning there will be a session for invited papers on **Fission,** with J. A. Wheeler, R. W. Spence, and R. B. Leachman as speakers. An invited paper by Burton Henke will precede one of the three parallel sessions for contributed papers on Wednesday afternoon. On Thursday morning there will be a session devoted to **Cosmic Rays.** The speakers will be Kurt Sitte, C. D. Anderson, R. B. Brode, M. S. Vallarta, and W. D. Walker. Also, on Thursday morning, the Division of Fluid Dynamics presents three invited papers by G. Guderley, J. D. Cole, and A. Busemann. On Thursday afternoon there will be invited papers on **Neutron Diffraction** by W. C. Koehler and M. K. Wilkinson, and two papers on the detection of the **Free Neutrino** by Frederick Reines and C. L. Cowan, Jr. Thursday evening at 8:00 P.M. Enrico Fermi, the President of the Society, will give a public lecture on Developments in High Energy Physics. There will be a session of invited papers on Friday morning, with R. F. Taschek, W. A. Fowler, C. McClelland, M. Goldhaber, and L. M. Langer as speakers, and a parallel session on **Atmospheric Physics,** with E. J. Workman, R. E. Holzer, F. L. Whipple, William Liller, and E. F. Cox as speakers. Friday afternoon will in part be devoted to a discussion on artificial mesons with E. Fermi as the leader. Among those participating will be H. Bethe, J. Lepore, Frank Crawford, R. F. Christy, and R. L. Walker. It is expected that others will be co-opted by the discussion leader.

The **banquet** of the American Physical Society will be held on Friday evening at 7:00 P.M. in the Hilton Hotel. Alan T. Waterman, the Director of the National Science Foundation, will be the after-dinner speaker. Advance reservations may be made by use of the form on the inside back-cover page. The price will be $3.50. **Banquet tickets** will be sold at the registration desk. The deadline for dinner reservations will be 5:00 P.M. on Wednesday.

Post-deadline ten-minute papers, pertaining to very recent achievements of very special importance, will be considered for admission to a special supplementary programme if the abstracts are received not later than Friday, August 28, in the office of the Local Secretary for the Pacific Coast. The titles of such papers as may be accepted will be announced on a blackboard near the registration desk.

For **prospective meetings** of the Society and the corresponding deadlines, see page 5 of this Bulletin.

Titles and abstracts of the papers contributed to the 1953 Albuquerque meeting are printed hereinafter, and in exactly this form they will appear in a future issue of *The Physical Review*. Errata will be printed on an adjacent page of *The Physical Review* if received not later than Friday, September 18, by Miss Ruth Bryans, American Institute of Physics, 57 East 55th Street, New York 22, New York. Do not send in the abstract marked with corrections: write out the corrections in the form "instead of . . . read . . ." Add nothing.

J. KAPLAN, *Local Secretary for the Pacific Coast*
University of California
Los Angeles 24, California

This is the Summons Card for the 1953 Winter Meeting in the West

This notice supplants the hitherto customary summons card for the 1953 Winter Meeting in the West to be held at Stanford University from December 28 to December 30, 1953. Tuesday, December 29, will be devoted entirely to a Symposium on Nuclear Magnetism. Instead of an evening banquet, the Society will have a luncheon on Tuesday in the Stanford Union dining room, at a price of approximately $2.00 per person.

A residence hall will be open, with registration between 4:00 P.M. and midnight, on Sunday, December 27. Attendants can stay any or all of the four nights of Sunday, Monday, Tuesday, and Wednesday and must leave not later than 9:00 A.M. on the morning of Thursday, December 31. The charge will be $3.00 for one night, $6.00 for two nights, $8.50 for three nights, and $11.00 for four nights. There will be adequate meal facilities, probably in the cafeteria.

Deadline will be Monday, October 19, at Los Angeles. Abstracts of contributed papers are to be sent to the address below, and must reach it not later than Monday, October 19. Send two double-spaced typewritten copies, original and carbon. Remember that an abstract must not be longer than 200 words or the equivalent thereof. In reckoning equivalence, a "display" formula (one that must occupy a line or more by itself) is an expensive luxury equated to 40 words; each line in a table counts as 10 words, each footnote as 10 words. Confine each abstract to a single page.

J. KAPLAN, *Local Secretary for the Pacific Coast*
University of California
Los Angeles 24, California

Preliminary Announcement of the 1954 Annual Meeting

This notice supplants the formerly customary summons card for the 1954 Annual Meeting. This meeting will be held in New York City, in the buildings of Columbia University, on Thursday, Friday, and Saturday, January 28, 29, and 30, 1954. The official hotel is The New Yorker: reservations should be made by letter to the hotel at an early date, with mention of the Society. Among the features of this meeting will be the Retiring Presidential Address, to be delivered by Enrico Fermi, at a joint ceremonial session with the American Association of Physics Teachers which we expect will also comprise the Richtmyer Lecture and the presentation of the Oersted Medal of that Association. Since 1954 is the Bicentennial Year of Columbia University, there will be a programme of papers devoted to the contributions of that University to physics and to a record of its beneficence to our Society.

Deadline will be Friday, November 20, 1953.

Abstracts of contributed papers are to be sent to the address below, and must reach it not later than Friday. Send two double-spaced typewritten copies, original and carbon (not two carbons!). Confine each abstract to a single page. Remember that an abstract must not be longer than 200 words or the equivalent thereof. In reckoning equivalence, a "display" formula (one that must occupy a line or more by itself) is counted as 40 words, each line in a table as 10 words, and each footnote as 10 words.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York 27, New York

(Please keep this page on file!)

MEETINGS AND DEADLINES FOR THE SEASON 1953–1954

Ideally the deadline-to-meeting interval should be so chosen as to minimize the sum of two evils. One of these derives from the fact that the earlier the deadline, the greater the number of results that fail to be ready in time for presentation at the meeting. The other is due to the fact that the later the deadline, the later the Bulletin reaches our members, and the greater the number of these who cannot make plans for travel after they know the programme of the meeting. If it be true that silence gives consent, more than 95 percent of the members of the American Physical Society are satisfied with deadlines and Bulletins as late as those of the season just ending. Yet it does seem as though we had yielded too far to those who prefer late deadlines, to the displeasure of those who prefer early Bulletins. The Council has authorized the lengthening of the deadline-to-meeting interval to ten weeks. This will be done for the New York and Washington meetings of 1954, also for the West Coast meeting of the holiday week (not because we apprehend an enormous size for this convention, but because it is disadvantageous to entrust the Bulletin to the mails during the pre-Christmas rush). For the Thanksgiving and the March meetings, the interval will be nine weeks; for the Austin and the Minneapolis meetings, eight weeks.

I. Meetings east of the Rockies

Place	*Meeting dates*	*Deadline dates*
Chicago	November 27–28, 1953	September 25
New York	January 28–30, 1954	November 20
Austin	February 26–27	December 30
Detroit-Ann Arbor	March 18–20	January 15
Washington	April 29–30, May 1	February 19
Minneapolis	June 28–30	April 30

Abstracts of contributed papers for the foregoing meetings are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York. To avoid danger of confusion, please do not send abstracts for any meeting until the deadline date of the previous meeting is past.

II. Meetings west of the Rockies

Stanford	December 28–30, 1953	October 19
Seattle	July 7–10, 1954	May 5, 1954

Abstracts of contributed papers for these two meetings are to be sent to J. Kaplan, University of California, Los Angeles 24, California.

EPITOME OF THE 1953 NEW MEXICO MEETING

(Personal names are those of invited speakers, except that Mitchell stands for Mitchell Hall; SUB stands for Student Union Building Ballroom.)

Wednesday

10:00	A.	Spence, Leachman, Wheeler. SUB.
2:00	B.	Henke. Contributed papers. Mitchell 101.
2:00	C.	Contributed papers. Mitchell 102.
2:00	D.	Contributed papers. Geology Auditorium.

Thursday

9:00	E.	Sitte, Brode, Walker, Anderson, Vallarta. Contributed papers. SUB.
9:00	F.	Division of Fluid Dynamics: Guderley, Cole, Busemann. Contributed papers. Geology Auditorium.
2:00	G.	Wilkinson, Koehler, Reines, Cowan. Contributed papers. SUB.
4:15	H.	Contributed papers. Mitchell 101.
4:15	I.	Contributed papers. Mitchell 102.
8:00	J.	Public Lecture: Fermi. SUB.

Friday

9:00	K.	Langer, Goldhaber, McClelland, Taschek, Fowler. Contributed papers. SUB.
9:00	L.	Cox, Liller and Whipple, Workman, Holzer. Contributed papers. Geology Auditorium.
2:00	M.	Discussion on artificial mesons: Fermi. SUB.
4:15	N.	Contributed papers. Mitchell 101.
4:15	O.	Contributed papers. Mitchell 102.
4:15	P.	Contributed papers. Mitchell 122.
7:00		Banquet of the American Physical Society. Hilton Hotel.

Saturday

Excursions (to be announced).

PROGRAMME

WEDNESDAY MORNING AT 10:00

Student Union Ballroom

(DAROL FROMAN, presiding)

Invited Papers

A1. Fission with Moderate Energy Neutrons. R. W. SPENCE, *Los Alamos Scientific Laboratory.* (30 min.)

A2. The Energy Released in Fission. R. B. LEACHMAN, *Los Alamos Scientific Laboratory.* (30 min.)

A3. Fission and Nuclear Models. JOHN A. WHEELER, *Princeton University.* (45 min.)

WEDNESDAY AFTERNOON AT 2:00

Room 101, Mitchell Hall

(E. J. WORKMAN, presiding)

Invited Paper

B1. The Size-Determination of Submicroscopic Particles by Long Wavelength X-Ray Diffraction. BURTON HENKE, *California Institute of Technology.* (30 min.)

Contributed Papers

B2. Acoustic Approximation to Weak Shock Diffraction. CRAIG C. HUDSON, *Sandia Corporation.*—Using Friedlander's[1] application of the Sommerfeld diffraction formula, the pressure fields for the diffraction of a weak shock by right-angle wedges has been approximated. The total field is separated into a diffraction region and a turbulence region by the free boundary formed by the contact of the vortex with the surface. The Friedlander formulas are applied in the diffraction region with good agreement to experimentally obtained fields. An anomaly is pointed out in the case of a back corner where the acoustic approximation cannot work. Calculations are made for both square and peaked waves.

[1] Friedlander, Proc. Roy. Soc. (London) **186**, 322–67 (1946).

B3. Properties of the Hugoniot Function.* R. D. COWAN, *Los Alamos Scientific Laboratory.*—The Hugoniot relation $E(p, v)=E_0+(p+p_0)(v_0-v)/2$ (where $E(p, v)$ and E_0 are, respectively, the internal energies of the material behind and in front of the shock) together with the equation of state of the material behind the shock defines a Hugoniot curve in the (p, v) plane. In terms of the Hugoniot function $H(p, v) \equiv E(p, v)-E(p_0, v_0)+(p+p_0)(v-v_0)/2$, the Hugoniot relation becomes $H(p, v)=E_0-E(p_0, v_0)=\text{constant} \gtrless \text{zero}$. (The equality sign holds if the material is not altered chemically by the shock; the inequality holds otherwise, as for example in the detonation of high explosive.) The differential of the Hugoniot function may be written $dH=TdS+\{(v-v_0)dp-(p-p_0)dv\}/2 = TdS+r^3d\theta/2$, where r and θ are the polar coordinates of (p, v) referred to (p_0, v_0) as the origin. Given a family of adiabats $dS=0$, this expression provides a simple means of mapping qualitatively the family of curves $dH=0$ (one of which is the actual shock curve) and of deriving properties such as the variation of entropy along the curves.

* An extension of a paper by H. Weyl, AMG-NYU No. 46 (AMP Note No. 12).

B4. New Studies of Nitrogen Afterglows.* MARX BROOK, *University of California, Los Angeles.*—A flow system was used to mix the nitrogen afterglow with a rare gas downstream from the discharge. The intensity distribution in the first positive afterglow bands was compared with the intensity modifications produced by mixing nitrogen with a rare gas prior to the discharge. The same intensity shifts to the red are produced in both cases. An analysis of the current theories of active nitrogen will be given in the light of the results. It will be shown that the Cario-Kaplan hypothesis as well as the molecular ion theory of Mitra cannot account for the nitrogen afterglow. The most probable mechanism is an atomic recombination process in a three-body collision. The transition from the $^5\Sigma$ to the $B^3\Pi$ state is forced by the collision,

$$[N+N \rightleftarrows N_2(^5\Sigma)]+N_2 \rightarrow N_2(B^3\Pi)+N_2, \quad N_2(B^3\Pi) \rightarrow N_2A^3\Sigma+h\nu.$$

* This work has been sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.

B5. Quantitative Analysis of the Lower Ionosphere.* H. K. KALLMANN, *University of California, Los Angeles.*—A quantitative analysis has been made of the physical properties of the atmosphere between 80 km and 130 km altitude. Average pressure density and temperature, as well as individual particle concentration and electron densities, have been calculated. In accordance with theory and observation, one can now be certain that molecular oxygen is dissociated under the influence of solar radiation, and that molecular and atomic oxygen is ionized by solar radiation of $\lambda<1000$A and $\lambda<910$A, respectively. Taking this into account, it has been found that the calculated density and pressure data are in good agreement with the observed data as presented in the Rocket Panel Report.[1] The temperatures obtained between 80 km and 220 km are between the maximum and minimum values proposed by the Panel. When the calculated values for neutral particle

densities are used to determine the radiation effect of the sun upon the lower ionosphere, the variation of electron density with altitude is found, corresponding to the so-called *E* layer. Contrary to present-day investigations, a continuous and not a parabolic electron layer formation is obtained.

* This work has been sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.

[1] The Rocket Panel. Phys. Rev. **88**, 1027 (1952).

B6. Pulsed Searchlight System for Upper Atmosphere Density Studies.* S. S. FRIEDLAND, H. S. KATZENSTEIN, J. KATZENSTEIN, D. P. LINDORFF, G. S. TIMOSHENKO, AND L. E. WILLIAMS, *The University of Connecticut.*—A pulsed searchlight system has been developed to measure the light scattered at various altitudes of the upper atmosphere. A Westinghouse FGL-1 krypton-filled flash lamp is placed at the focus of a 60-in. searchlight. The lamp is loaded at 100 watt-sec and discharged with a 20μsec pulse width by a manual trigger. An RCA 5819 photomultiplier is placed at the focus of a similar searchlight located at the same site; both searchlights being directed vertically upward. The photomultiplier is "gated on" for a period of 20μsec as follows: (1) the "reference gate" is opened at a time after the flash sufficient for the light to travel up to and back from a reference altitude. (2) The "measurement gate" is opened at a time after the flash sufficient for the light to travel up to and back from any desired altitude. (3) The "noise gate" is opened at a time sufficiently long after the flash so that light detected by the photomultiplier consists only of background light. The pulse from the noise gate is subtracted from the pulse from the measurement gate pulse. The resulting signal is compared to the reference gate pulse. It is assumed that the ratio in light scattering between the signal and reference altitude is the same as the ratio of molecular densities of the atmospheres at these altitudes.

* The research reported in this paper has been sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.

B7. Stratospheric Temperature Profiles Obtained from Searchlight Measurements. L. ELTERMAN, *Air Force Cambridge Research Center.*—Measurements of atmospheric densities have been made with the "searchlight technique," using improved instrumentation.[1] The density distributions are sufficiently accurate so that corresponding temperature profiles are readily obtained. The density-temperature equation requires the evaluation of an integration constant, which is accomplished by using radiosonde information and, in addition, considering physically acceptable temperature lapse rates. Five temperature profiles are derived up to 60 km which represent stratospheric conditions over New Mexico during October 1952.

[1] L. Elterman, Geophysics Research Paper No. 10, 1951.

B8. Seasonal Trend of Atmospheric Ozone as Revealed by the Solar-Telluric Band at 9.6 Microns.* ARTHUR ADEL, *Arizona State College.*—An extensive record has been obtained of the absorption of solar radiation by atmospheric ozone in the interval 9.2 to 10.1 microns. Seventy-two independent observations made on seventy days are scattered over the various months of the year. The data are suitable for a first examination of the seasonal trend of stratospheric ozone as revealed by an infrared band. The absorptions are reduced to a quantity proportional to the amount of ozone, and the curve of seasonal change in this quantity is strikingly similar to the seasonal trend in ozone as revealed by the long-accepted method of ultraviolet absorption. This further usefulness of the 9.6-micron band of ozone as an atmospheric parameter is thus established.

* Supported in part by the Geophysics Research Division, Air Force Cambridge Research Center, Air Research and Development Command.

B9. Atmospheric Ozone Fluctuations at Albuquerque.* I. GERALD BOWEN, *University of New Mexico.*—The concentration of surface ozone measured at Albuquerque shows morning peaks which occur under certain meteorological conditions. The peaks are observed near the time when the stable night-time lapse rate becomes adiabatic in the lower layers. The value of the ozone concentration reached during such a morning peak often is the highest for the day; occasionally it is exceeded by later rises. The rate of surface heating is sometimes reduced at the time of the ozone peaks, simultaneously with the destruction of the stable lapse rate. This phenomenon does not occur if surface winds during the night have mixed the lower air to a considerable height, or if for any reason the nocturnal lapse rate has remained fairly steep.

* Supported by Air Force Cambridge Research Center, Air Research and Development Command.

B10. Variation of Natural Radioactivity in the Atmosphere with Altitude. MARVIN H. WILKENING, *New Mexico Institute of Mining and Technology.*—A study of the vertical distribution of radon and its decay products in the lower atmosphere has been made utilizing data taken during plane flights and at ground stations having different altitudes. The vertical span ranged from ground level (4000 feet) to 16 000 feet for the plane flights and from 4600 to 10 300 feet for the ground-level measurements. An alpha scintillation detector was used to count samples collected both by electrostatic precipitator and "negative wire" techniques. The limited precipitator data obtained suggest that on typical fair-weather days, the decrease of activity with altitude in the lower atmosphere is approximately linear and drops to one-half its ground-level value in about 2500 feet. The negative wire samples show a smaller decrease in activity with altitude. A monitor using an electrostatic precipitator for sample collection was operated at four ground-level stations each at a different altitude. The average activity decreased with altitude in much the same way as did the precipitator samples collected in the plane flights. Under ideal conditions the general decrease in activity with altitude can be explained in terms of the decrease in density, radioactive decay, and vertical transport by eddy diffusion in the atmosphere.

B11. Critical Conditions For Ice Formation on Silver Iodine Nuclei.* ROBERT J. MCCARTY,† *New Mexico Institute of Mining and Technology.*—The time interval between exposure of dry silver-iodide nuclei to water vapor and the appearance of a microscopic ice crystal is measured as a function of the nuclei temperature and the water-vapor pressure. The time interval becomes very long as certain critical combinations of nuclei temperature and water-vapor pressure are approached, the approach being made conveniently along either a path of constant nuclei temperature or along a path of constant water-vapor pressure. Values for the critical conditions are approximated by extrapolating to infinite time an empirically derived function relating the observed time intervals to the variable condition. Two sets of critical conditions have been determined for ice formation on silver iodide nuclei, one corresponding to the set of dew points, the other lying between the set of dew points and the set of frost points.

* Supported by the U. S. Office of Naval Research.
† Now at the Alamogordo Air Base.

B12. Electron Traps in Ice. E. AVERY, L. GROSSWEINER, AND M. MATHESON, *Argonne National Laboratory.*—Measurement of thermoluminescence in ice irradiated with hard x-rays at $-196°C$ has shown that the nature of the glow curve varies with the purity and irradiation history of the sample. The thermoluminescence associated with pure well-annealed ice of low-oxygen content showed distinct glow peaks at $-165°C$, $-117°C$, and $-97°C$ for heating rates of several degrees per

minute. The most prominent peak, at −117°C, obeyed first-order kinetics with a trap depth of 0.26 ev and frequency factor of 1.9×10^{8} sec^{-1}. Ice which contained oxygen, either by direct addition or diffusion in from the atmosphere, exhibited decay over a broad temperature range. The presence of hydrogen peroxide, whether added or formed *in situ* by heavy irradiation, suppressed all glow peaks markedly. The interpendence of the glow peaks and the nature of the electron traps and luminescent centers will be discussed.

B13. New Method for the Approximate Calculation of Effective Ionic Radii. N. EFREMOV, *1061 Intervale Avenue, New York 59, New York.*—A new form of the periodic system of ions (consisting of three segments: ions with negative valence from 4 to 1, left; ions with positive valence from 1 to 4, middle; and ions with positive valence from 4 to 7, right segment) has been proposed. Its generalized scheme is a matrix consisting of several series of total numbers (1, 2, 3, 4, 5, 6, 7, etc.). These matrix numbers characterizing ions are coefficients used for the calculation of all the effective ionic radii for the crystalline lattices of the NaCl type. Other coefficients used for the calculation of ionic radii are: the principal quantum number n and a certain constant (P or P') which can be derived from the Rydberg constant (calculation of the ionic radii of the positive elements with high valence) or the constant P or P' and the matrix number characterizing the tetravalent positive ions of the given period (calculation of the radii with positive and negative valence from 1 to 4). Values calculated by this method are in substantial agreement with the values determined by Goldschmidt and Pauling.

WEDNESDAY AFTERNOON AT 2:00

Room 102, Mitchell Hall

(R. E. HOLZER, presiding)

Contributed Papers

C1. Spectral Distributions of Filtered X-Ray Beams. W. J. RAMM and M. N. STEIN, *Signal Corps Engineering Laboratory.*—The energy distribution of the radiation from a commercial x-ray tube was analyzed with a pulse-height spectrometer for several tube potentials and various amounts of filtration. The results are compared with empirically calculated distributions obtained by using Kramer's well-known formula for the distribution of continuous x-ray spectra. The selection of absorbers to obtain a desired spectral distribution and certain aspects of the calculations will be discussed.

C2. The Long-Lived Phosphorescent Components of Thallium-Activated Sodium Iodide. L. R. MEGILL AND C. R. EMIGH, *Los Alamos Scientific Laboratory.*—Using a Co^{60} source as a means of primary irradiation, the long-lived phosphorescent decay of thallium-activated sodium iodide crystal has been studied at a crystal temperature of 29.9±0.1°C. A set of decay curves has been obtained by using different primary radiation exposure times varying from 5 seconds to 120 hours. These curves have been arbitrarily analyzed in terms of exponential decay components. The following set of mean lives for the different trap depths are consistent with all these complex decay curves: 0.23±0.04, 0.92±0.11, 3.1±0.3, 8.8±0.8, 28±3, 90±3, and 510±100 minutes. The initial intensities of the exponential components approach constant values with an increase in exposure time and to a first-order approximation follow a very simple monomolecular trap theory. The effect on the mean lives which is due to a change in the crystal temperature will be discussed. The data have been obtained using a 5819 photomultiplier as the detector and a vibrating reed electrometer to measure the current output of the photomultiplier.

C3. Magnetoelectrostatics. E. T. BENEDIKT, *Convair (Consolidated Vultee Aircraft Corp.).*—The possibility of producing electrostatic fields by means of unhomogeneous magnetic fields has been considered in the past by the author.[1] This effect is due to the mechanical force to which a system of magnetically polarized particles is subjected when under the action of an unhomogeneous magnetic field. If these particles are, in addition, electrically charged, their (necessarily non-uniform) equilibrium distribution will be characterized by an electrostatic field. The results of new theoretical studies regarding classical and quantum-mechanical as well as thermodynamical aspects of these phenomena will be presented.

[1] Paper given at the June 1948 meeting of the American Physical Society in Pasadena, California. Abstract appeared in Phys. Rev. **74**, 1563 (1948).

C4. Topology of Magnetic Fields. W. M. ELSASSER AND K. MCDONALD, *University of Utah.*—Textbooks state that the condition $\nabla\cdot H=0$ implies that the magnetic lines of force are closed. Following Slepian,[1] who points out that this is not generally true, we have tried to put his arguments into quantitative form. If the electric current-density is assumed continuous everywhere, the family of field lines has singularities only at points or curves where $H=0$, but the condition $\nabla\cdot H=0$ prevents the lines from terminating there. The fields whose lines close upon themselves are characterized by certain symmetry or other restrictive conditions, for instance, that each line be confined to a plane. In the general case a line approaches arbitrarily close to any point of at least a region of space ("ergodic" behavior). Studies of this behavior may be used to advantage to clarify the conditions under which amplificatory processes in magnetohydrodynamics can or cannot[2] occur.

[1] J. Slepian, Am. J. Phys. **19**, 87 (1951).
[2] T. G. Cowling, Monthly Notices Roy. Astron. Soc. **94**, 39 (1934).

C5. Magnetic Shielding Produced by a Rotating Conducting Tube. ALFREDO BAÑOS, JR., *University of California, Los Angeles.*—The problem of deflecting the beam in high-energy accelerators employing an intense magnetic field or the problem of obtaining a field free region over a limited volume between the pole pieces or in the fringing field may possibly be solved by using a conducting tube rotating at right angles to the magnetic field. Because of eddy currents, the field inside the tube, which turns out to be uniform, is materially reduced and can be oriented in any direction (on a plane perpendicular to the axis of the tube) by adjusting the available parameters: ratio of outer to inner radius, conductivity of the material, permeability of the material (assumed constant for magnetic materials), and angular frequency of rotation. The power requirements are determined in terms of these parameters, and it is shown that for copper and iron

tubes the required power per unit of length may not be prohibitive at 60 cycles if the magnetic field to be shielded does not exceed 10 000 gauss. Power requirements for solid shafts are also considered in this investigation, and the results obtained are found in complete agreement with those of Frank.[1]

[1] N. H. Frank, "Eddy current losses in a conducting shaft rotating in a magnetic field," M. I. T. Research Laboratory of Electronics, Report No. 23 (November 20, 1946).

C6. Distribution of Sizes of Spheres in a Solid from a Study of Slices of the Solid. WALTER P. REID, *U. S. Naval Ordnance Test Station.*—It is assumed that spheres are distributed throughout an otherwise uniform solid and that one wishes to determine the distribution of sizes among these spheres from the distribution of sizes among circles observed when the solid is cut by a plane. Integral equations have been determined connecting functions used to represent various size distributions of circles and of spheres so that any of the functions may be calculated if one of them is known. Another possibility is to draw random lines on the planes and determine the distribution of sizes of the intercepted chords. To determine information concerning the number of spheres of a given size, it is only necessary to have information about the chords in the neighborhood of that size or the circles of that size and larger. Corresponding frequency distribution curves for spheres, circles, and chords have been calculated.

C7. Cleavage Surfaces of Germanium Crystals. I. H. CHRISTENSEN, C. J. CALBICK, AND E. E. THOMAS, *Bell Telephone Laboratories, Inc.*—Single crystals of germanium were cleaved on (111) planes and the resulting surfaces examined optically, electron-optically, and by x-rays. Two particular samples, I and II, are discussed in this and the following paper. Both crystals showed the exceedingly low fracture strength characteristic of germanium.[1] The cleavage was cataclysmic in nature since fracture striae attributable to clearly defined and complex shock wave systems[2] were seen. Sample I, drawn from the melt in the standard way, showed about 25 percent of the cleavage surface to be imperfect. Sample II, drawn from the melt of previously zone-refined material,[3] showed imperfections in 5–10 percent of its surface. Sample I was n type with $\rho = 50$ ohm-cm and hole lifetime of 260 μsec, while sample II possessed intrinsic conduction at room temperature with a donor-minus-acceptor concentration of about $3 \times 10^{12}/\text{cm}^3$. Cracking phenomena observed optically on these and other germanium surfaces are believed to stem from defects in the original crystal structure.

[1] E. E. Schumacher, Am. Inst. Mining Met. Engrs. Trans. **88**, 1097 (1950).
[2] Nadai, *Theory of Flow and Fracture of Solids* (1950), Vol. I, p. 204.
[3] W. G. Pfann and K. M. Olsen, Phys. Rev. **89**, 322 (1953).

C8. Cleavage Surfaces in Germanium Crystals. II. C. J. CALBICK, H. CHRISTENSEN, AND E. E. THOMAS, *Bell Telephone Laboratories, Inc.*—The cracking phenomena described in germanium samples I and II of the previous paper are more strikingly shown by electron than by optical micrography. In addition to enhanced detail in rough and fissured areas, smooth areas traversed by cleavage steps only were observed. It was noted also that the relatively more imperfect sample I showed correspondingly more numerous cracks and greater extent of rough areas than sample II. The complex surface structure must have its basic cause in imperfections existing in the crystal before cleavage. Seitz' theory[1] of coalescence of vacancies into sheets, followed by collapse of the sheets with formation of dislocation rings, has recently received experimental confirmation by Hoffman, Anders, and Crittenden,[2] who measured the stresses during annealing of nickel films deposited by evaporation. The sheets of vacancies are reminiscent of the microcracks of the Griffith theory of fracture strength. It is suggested that during the cataclysmic process of cleavage, such microcracks may enlarge and widen to form the observed cracks, which are of the order of 200A wide.

[1] F. Seitz, *Advances in Physics* **1**, 43 (1952).
[2] Hoffman, Anders, and Crittenden, J. Appl. Phys. **24**, 231 (1953).

C9. A Single Crystal Neutron Diffraction Study of Heavy Ice. S. W. PETERSON AND H. A. LEVY, *Oak Ridge National Laboratory.*—The structure of heavy ice at $-50°$C has been investigated by means of the single-crystal neutron diffraction method. Complete (01·0) zone data was obtained out to $\sin\theta/\lambda = 0.77$. Fourier and least-squares procedures were used in structure refinement. The deuterium atoms were found to be in disordered positions corresponding to a double minimum potential barrier in full agreement with the Pauling model of ice and with the powder diffraction data of Wollan, Davidson, and Shull.[1] The short deuterium oxygen distance was found to be 1.01A and the D–O–D angle closely tetrahedral. A few measurements made at $-130°$C indicated no significant structural difference at the lower temperature. The resulting centrosymmetrical structure is not compatible with the piezoelectricity[2] sometimes claimed for ordinary ice. In addition it does not support, but is not definitely incompatible with, Bjerrum's considerations[3] on the nature of the disorder in ice.

[1] Wollan, Davidson, and Shull, Phys. Rev. **75**, 1348 (1949).
[2] Rossmann, Experientia **6**, 182 (1950).
[3] Niels Bjerrum, Science **115**, 385 (1951).

C10. Behavior of Metals at Elevated Temperatures. EDWARD W. LAROCCA, *U. S. Naval Ordnance Test Station.*—Measurements of rupture times of a chromium-nickel-iron alloy were made in various atmospheres and at varied temperatures and stresses. The activation energy of the rupture process is shown to be stress-dependent and not constant over the temperature range studied, 900° to 1200°C.

C11. Reformulation of Solid-State Electronic Boltzmann Equation. J. S. LOMONT, *U. S. Naval Ordnance Test Station.*—The customary derivation of the Boltzmann transport equation for conduction electrons in crystals assumes that $\partial_t f$ is the sum of two terms due to external fields and collision processes. The collision term is expressed in terms of a transition probability, and explicitly takes account of the exclusion principle; whereas the field term is derived on classical grounds and ignores both the exclusion principle and the binding of the electrons. The derivation is therefore a hybrid one, half classical and half quantum mechanical. If one re-examines the derivation of the collision term, one sees that this term will give the entire $\partial_t f$ if the transition probability due to collisions is replaced by the transition probability due to both the external fields and collisions. The resulting new form of the Boltzmann equation is thus given a unified quantum-mechanical derivation. To compare the two forms of the equation, one can (and must), without recourse to perturbation theory, calculate the transition probability of free electrons due to an external electric field. Using this to calculate the field term one gets the old $(\mathbf{F} \cdot \nabla_k f)$ term plus a term nonlinear in the distribution function. The corresponding general calculation for the tight-binding approximation cannot be made.

C12. Elastic Description of a High-Amplitude Spherical Pulse in Steel. WILLIAM A. ALLEN, *U. S. Naval Ordnance Test Station.*—Extensive calculations have been performed with the IBM card programmed electronic calculator to evaluate a problem in elasticity that simulates the effect of a cylindrical charge of high explosive detonated in intimate contact with a steel plate. Although elastic theory has been extrapolated into a regime where it is known not to apply, insight can be obtained on the origin of the negative component of the pulse which produces tensile fracture in the specimen.

Agreement between experiment and elastic theory improves as the stresses decay to sonic proportions.

C13. Suppression of AlO in the Wake of Ultra-Speed Pellets. WILLIAM C. WHITE, *U. S. Naval Ordnance Test Station.*—Time-resolved spectrograms of aluminum ultra-speed pellets have been obtained along trajectories where the velocity is decreasing rapidly. The AlO bands were observed to be suppressed for a length of time depending upon the position of the pellet along its trajectory. The time of suppression is a few μsec at the beginning of the trajectory, a maximum of over 100μsec at five feet, and goes to 0μsec at approximately 12 feet. It is felt that after the pellet reaches the five-foot point where its velocity is about 4.5 km/sec, the suppression of AlO becomes velocity-dependent and hence may be controlled by the temperature behind the shock wave.

C14. Electrical Conductance and Structure Studies of Thin Bi Films Evaporated on Glass* P. J. BRYANT, H. U. RHOADS, AND A. H. WEBER, *Saint Louis University.*—The electrical conductance[1] of thin Bi films (thickness 2–310A) evaporated in vacuum onto glass substrates was measured and correlated with an electron microscope and electron diffraction examination of the films. Film thickness was determined by a radioactive tracer method.[2] Preparation of the standard deposits, construction of the conductance apparatus, and the technique of sample preparation are described. The electrical conductance for films about 0.5×0.15 cm in surface dimensions was sensibly constant at 1.30×10^{-14} ohm^{-1} for thin deposits (2–75A). A transition region was found between 90–130A in which the conductance increases by a factor of 10^{12}. Electron micrographs show film structures for which the observed conductance changes are the expected ones. For the region 2–20A the structure consists of flower-like deposits of Bi along with large areas void of metallic deposit; at about 20A small dispersed particles appear, these particles form separate aggregates for thicknesses up to about 90A. The aggregates then form into a structure of continuous paths. At 310A electrical resistivity is 1.60×10^{-4} ohm-cm (bulk metal value, 1.19×10^{-4} ohm-cm), and the structure is virtually continuous.

* Assisted by a National Science Foundation grant.
[1] L. W. Friedrich and A. H. Weber, Phys. Rev. **66**, 248 (1944); D. F. O'Brien and A. H. Weber, Phys. Rev. **60**, 574 (1941).
[2] J. J. Antal and A. H. Weber, Rev. Sci. Instr. **23**, 424–26 (1952).

C15. The Effects of High Sputtering Rates on the Resistivities of Sputtered Gold Films.* RICHARD B. BELSER, *Georgia Institute of Technology.*—Measurement of the temperature of a glass substrate subjected to sputtering from a 2-inch disk gold cathode at 100-ma sputtering rate indicated that temperatures as high as 250–300°C were experienced. These temperatures are sufficient to cause artificial aging of sputtered gold films. Initial resistivity measurements of gold films sputtered at successively higher currents in 20-ma steps showed a decrease in initial resistivity from $5.3\rho_b$ at 20 ma to $3.7\rho_b$ at 100 ma. These films, however, upon artificial aging in an infrared vacuum oven dropped in resistivity to values under $2\rho_b$. These tests have indicated that sputtered gold films are very resistant to artificial aging in comparison with evaporated gold films or sputtered silver films. Resistance stability is also displayed at room temperature. The apparent stability of these films is of importance in their use for coatings of quartz piezoelectric crystals.

* Supported by the U. S. Army Signal Corps.

WEDNESDAY AFTERNOON AT 2:00

Geology Auditorium

(W. A. FOWLER, presiding)

Contributed Papers

D1. Effects of Chemical Structure on Stopping Powers for High-Energy Protons.* T. J. THOMPSON,† *University of California Radiation Laboratory, Berkeley.*—A study has been made of the stopping power of various elements and compounds for a high-energy proton beam. The stopping powers of four elements hydrogen, carbon, nitrogen, and oxygen and twenty-nine compounds of these elements have been measured with a high degree of accuracy. The stopping power of a fifth element, chlorine, has been inferred from its compounds. An effort has been made to determine whether or not the relative stopping power of a compound is strictly an additive function of the elements which form the compound. The results indicate that the relative stopping power of a compound as a whole is an additive function of the elements in the compound to within about one percent. The largest percentage deviations occur with the hydrogen atoms in the compound and are of the order of two percent. The percentage deviations decrease rapidly with increasing atomic number. There appears to be a measureable chemical effect. For example, the stopping power of carbon and hydrogen is higher in unsaturated compounds than in saturated compounds.

* This paper is a complete report of work done at the University of California Radiation Laboratory and first reported in part at the Berkeley meeting of the American Physical Society, December 28, 1951.
† Now at University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

D2. The Disintegration of C^{12}, B^{11}, and B^{10} by Fast Neutrons.* GLENN M. FRYE AND LOUIS ROSEN, *University of California, Los Alamos Scientific Laboratory.*—Detailed measurements on the stars produced in C^{12} unloaded, B^{11} loaded, and B^{10} loaded Ilford *C2* emulsions by 12- to 20-Mev neutrons have been used to identify approximately 2000 $C^{12}(n, n')3\alpha$ reactions[1] and a small number of $B^{10}(n, 2\alpha)H^3$ and $B^{11}(n, \alpha)Li^{8*}\rightarrow Be^{8*}\rightarrow 2\alpha$ reactions.[2,3] The neutrons were generated by the large Los Alamos electrostatic accelerator, using the $T(d, n)He^4$ reaction. The emulsions were positioned around the circumference of a circle with the tritium target at the center. The geometry was such that the variation of the incident neutron energy at each plate was $\leq$0.8 Mev. Results will be given for the variation of cross section with energy for C^{12} disintegrations. An attempt is presently being made to determine whether this reaction proceeds through intermediate stages involving excited states of C^{12} and Be^8, and if so, which excited states are involved.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] L. L. Green and W. M. Gibson, Proc. Phys. Soc. (London) **A62**, 296 (1949).
[2] J. L. Perkin, Phys. Rev. **81**, 892 (1951).
[3] E. Pickup, Phys. Rev. **74**, 495 (1948).

D3. The Angular Distributions of the Long-Range α Particles from $N^{15}(p, \alpha)C^{12}$. G. C. NEILSON, D. B. JAMES, AND C. A. BARNES, *University of British Columbia*.—The angular distributions of the long-range alpha particles have been studied with a helium-filled proportional counter for proton energies between 0.5 and 1 Mev. The proton beam from the electrostatic accelerator bombarded evaporated KNO_3(60 percent N^{15}) targets about 20 kev thick. The angular distributions, normalized such that $I(90°)=1$, were multiplied by the yield at 90°[1] and analyzed into the form $A+B\cos\theta+C\cos^2\theta$.

Ep in Mev	A	B	C
0.500	1.13±0.03	−0.37±0.01	−0.11±0.04
0.750	1.40±0.09	−0.90±0.06	−0.11±0.13
0.850	3.00±0.13	−2.46±0.09	−0.45±0.19
0.900	4.10±0.18	−3.57±0.11	−0.53±0.24
0.950	6.50±0.17	−3.86±0.12	−2.64±0.24
0.975	7.60±0.26	−3.87±0.08	−3.76±0.38

Preliminary analysis indicates that the 0.338-Mev resonance corresponds to an O^{16} state of $J=0+$ formed with p-wave protons and the 1.05-Mev resonance to an O^{16} state of $J=1-$ formed with s and d-wave protons.

[1] Schart, Fowler, and Lauritsen, Phys. Rev. **86**, 525 (1952).

D4. The Gamma Rays from the $T(p, \gamma)He^4$ Reaction. J. B. WARREN AND G. M. GRIFFITHS, *University of British Columbia*.—Using scintillation counter technique the gamma-ray energy, measured relative to the $Li^7(p, \gamma)Be^8$ reaction, is 20.3±0.4 Mev at 90° to incident protons of 800-kev energy. This corresponds to a Q value of 19.7±0.4 Mev in accord with the mass values. The yield appeared to be lower than expected from previous work.[1] Preliminary data on the angular distribution show it to be nearly pure $\sin^2\theta$ and to be represented by $\sin^2\theta+0.13\pm0.03$ at $Ep=800$ kev. Neutrons are in evidence well below the (p, n) threshold.

[1] Argo, Gittings, Hemmendinger, Jarvis, Taschek, Phys. Rev. **78**, 691 (1950).

D5. The Gamma Rays from the $D(p, \gamma)He^3$ Reaction. G. M. GRIFFITHS AND J. B. WARREN, *University of British Columbia*.—Using scintillation counting technique the gamma-ray energy has been measured and fits the relation $E_{\gamma(90°)}=[5.50\pm0.03+\frac{1}{4}Ep]$ Mev. The Doppler shift of the gamma-ray frequency as a function of angle has been determined and has the full value expected assuming the gamma radiation is emitted in a time short compared to the slowing down time. The excitation function has been measured from 250-kev to 1.8-Mev bombarding proton energy and the cross section at 1 Mev is about 6×10^{-30} cm². Careful measurements of the angular distribution show, after allowing for the neutrons produced by knock-on deuterons, that there is a small yield at 0°. The distribution has the form $\sin^2\theta+b$ where $b=0.046\pm0.005$ for $Ep=1$ Mev and $b=0.025\pm0.006$ for $Ep=1.75$ Mev.

D6. A High-Pressure Cloud-Chamber Investigation of Protons Scattered by 300-Mev Neutrons.* JOHN DEPANGHER,† *University of California, Berkeley*.—An investigation of the protons scattered by 300-Mev neutrons has been conducted in a magnetic field with a Wilson cloud chamber filled with hydrogen at a pressure of ten atmospheres. The energy spectrum will be presented for the neutrons which are produced in a 1¾-in. thick LiD target by 340-Mev protons from the Berkeley cyclotron. The angular distribution data, consisting of 2057 tracks whose neutron energies exceed 200 Mev, cover the range of angles 10°–180° for the neutrons in the center-of-mass system. When the data are normalized to a total cross section of 35 mb, they agree well with the work of Kelly *et al.*,[1] but the yield of neutrons with small scatter angles is considerably below that which is predicted by phenomenological theories. Evidence for the reactions $n+p\rightarrow\pi^0+d$, $n+p\rightarrow\pi^++2n$, and $n+p\rightarrow\gamma+d$ will be presented.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
† Now with the Hanford Atomic Products Operation, General Electric Company, Richland, Washington.
[1] Kelly, Leith, Segrè, and Wiegand, Phys. Rev. **83**, 923 (1951).

D7. Gamma Rays and Internal Pairs from Be^9+H^1.* ROBERT J. MACKIN, JR., *Kellogg Radiation Laboratory, California Institute of Technology*.—Gamma radiation following $Be^9(p, \alpha)Li^{6*}$, resonant at $Ep=2.565$ Mev,[1] has been studied with a magnetic lens spectrometer using 1.9 percent resolution. The gamma-ray energy, determined from Compton and photoelectron spectra, is 3572±12 kev. It may be necessary to subtract a 26-kev Doppler shift from this figure. The internal-pair (positron) spectrum agrees most closely (to 4.5 percent) with the assignment of the radiation as magnetic dipole. The theoretical electric-quadrupole spectrum falls 13 percent above the experimental points, about 1.5 times the probable error. Theoretical spectra for all other assignments differ from experiment by more than twice the probable error. The magnetic-dipole character is consistent with other data pertaining to the states involved. Capture radiation from the same resonance is 10^{-3} times as intense and has energy 8.1±0.2 Mev. It thus appears to lead to the 0.72-Mev state of B^{10}. The soft cascade radiation was not detectable above the background from the 3.57-Mev gamma rays.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] R. B. Day and R. L. Walker, Phys. Rev. **85**, 582 (1952).

D8. Gamma Rays from $N^{14}(p, \gamma)O^{15}$.* C. W. LI, *Kellogg Radiation Laboratory, California Institute of Technology*.—Capture gamma radiations from $N^{14}(p, \gamma)O^{15}$ have been investigated with the primary object to get information on the levels of O^{15} corresponding to low-energy resonances in $N^{14}+p$, which are of importance in the production of stellar energy through the carbon-nitrogen cycle. Nitrogen gas targets, 10 to 20 kev thick, were used and the gamma rays were detected with a NaI(Tl) scintillation counter and registered by oscilloscope pictures and a ten-channel differential discriminator.[1] The excitation curve of gamma rays for the bombarding energy 0.6 to 2.5 Mev agreed with the main part of the excitation curve for the induced O^{15} positron activity.[2] A number of cascade transitions were revealed. For the 1.06-Mev resonance, the following gamma rays have been established: (1) 8.34 Mev, strong; (2) 3.04±0.03 Mev and 5.27±0.03 Mev, strong; (3) 1.46±0.03 Mev and 6.82±0.08 Mev, weak. Direct transitions to the ground state from all the resonances studied are relatively strong, probably indicating that the spins are not larger than 5/2 for the corresponding levels.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Woodbury, Day, and Tollestrup, Phys. Rev. (to be published).
[2] D. B. Duncan and J. E. Perry, Phys. Rev. **82**, 809 (1951).

D9. Elastic Scattering of Protons by N^{14}.* T. S. WEBB, C. W. LI, AND W. A. FOWLER, *Kellogg Radiation Laboratory, California Institute of Technology*.—Measurements have recently been made of the absolute differential cross section for the elastic scattering of protons by N^{14}, using a magnetic spectrometer with protons accelerated in the 2-Mev electrostatic generator. An arrangement has been made for condensing NH_3 on a copper backing by using liquid nitrogen, and the solid NH_3 targets so obtained have been used. Preliminary measurements for bombarding energies in the range 0.5 to 1.7 Mev have been made at $\cos\theta=-0.9$; $-1/\sqrt{2}$; $-1/\sqrt{3}$ and 0, where θ is the scattering angle in the center-of-mass system. Two prominent scattering anomalies were observed with

maxima at 1.07 and 1.60 Mev corresponding to the levels of O^{15} at 1.06 and 1.55 Mev as observed in the $N^{14}(p, \gamma)O^{15}$ reaction. These anomalies are superposed on a background which decreases less rapidly than the calculated Rutherford cross section, the experimental value being approximately equal to Rutherford at 0.7 Mev and rising to over twice Rutherford at 1.7 Mev. Further experimental work and analysis are now in progress.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

D10. Energy Levels in N^{14} from the Scattering of Protons by C^{13}.* EDMUND A. MILNE, *Kellogg Radiation Laboratory, California Institute of Technology.*—The differential cross section for the elastic scattering of protons by C^{13} has been determined in the energy range from 0.45 to 1.60 Mev at angles of 50, 90, 120, and 160 degrees in the center-of-mass system. Marked anomalies were found in the scattering at 0.556, 1.16, 1.47, and 1.55 Mev corresponding to the 8.06-, and 8.62-Mev levels in N^{14} reported by Seagrave[1] and two new levels at 8.90 and 8.98 Mev. The spins and parities of these states have been determined from a preliminary analysis of the data which also indicates an effect due to the broad resonance at 1.25 Mev in $C^{13}(p, \gamma)N^{14}$ reported by Seagrave. The assignment for the 8.06-Mev level is $J=1^-$, for the 8.62-Mev level $J=0^+$, and for the broad 8.70-Mev level $J=0^-$. For the 8.90-Mev level $J=2^-$ or 3^-, and for the 8.98-Mev level $J=1^+$, 2^+, or 3^+.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] John Seagrave, Phys. Rev. **85**, 197 (1952).

D11. Gamma-Rays from $Li^7(p, \gamma)Be^8$.* ALFRED A. KRAUS, JR.,† *Kellogg Radiation Laboratory, California Institute of Technology.*—The excitation functions of the γ rays from the reactions $Li^7(p, \gamma)Be^8$ and $Li^7(p, p'\gamma)Li^{7*}$ have been measured in the energy range of 400 kev to 1400 kev. The detector was a 1½-in. diameter by 2 in. long NaI(Th) crystal scintillation counter. The soft γ rays from the first excited state of Li^7 follow the excitation curve of Brown, Snyder, Fowler, and Lauritsen.[1] The hard γ rays from Be^8 exhibit the well-known resonance at the 441-kev proton energy. In addition they are also resonant at the 1050-kev resonance of the soft γ rays. Possible assignments of the spin and parity of the 18.14-Mev level of Be^8 will be discussed in the light of angular distribution measurements of the hard γ rays.

* Supported by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
† G. E. Fellow in Physics, 1952–1953.
[1] Brown, Snyder, Fowler, and Lauritsen, Phys. Rev. **82**, 159 (1951).

D12. Reactions and Scattering of Protons on Li^7.* D. A. LIBERMAN AND R. F. CHRISTY, *Kellogg Radiation Laboratory, California Institute of Technology.*—An analysis in terms of s- and p-wave phase shifts has been made of the recent data[1] on the elastic scattering of protons on Li^7 between energies of 360 and 1400 kev. The principal features of the elastic scattering in the neighborhood of the 440-kev resonance and also the spherical symmetry of the resonant γ rays are explained by a $J=1$ even compound state formed by p-wave protons with channel spins 1 and 2 in a ratio of 1 to 5. This particular channel spin ratio corresponds to a particular state in either an LS or jj coupling scheme. An analysis is also being made of the region about the 1030-kev resonance, including both the elastic scattering data and recent experiments in this laboratory on the angular distribution of the inelastically scattered protons.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] W. D. Warters, thesis, California Institute of Technology (1953) and a paper to be published in the Physical Review.

D13. Angular Distributions of the $F^{19}(p, \alpha)O^{16}$ Reaction.* R. W. PETERSON, W. A. FOWLER, AND C. C. LAURITSEN, *Kellogg Radiation Laboratory, California Institute of Technology.*—A study of the angular distributions of the three short-range alpha groups from the $F^{19}(p, \alpha\gamma)O^{16}$ reaction at proton capture resonances from 874 kev to 1.69 Mev has been undertaken. Preliminary measurements at the 874- and 935-kev resonances are in agreement with the level assignments of Seed and French.[1] The α_2 and α_3 groups were observed at several angles at the 874 resonance with high resolution, using photographic plates as the detector in order to determine if either was a doublet containing the 2^- state as predicted on the basis of the alpha-particle model. No evidence of such a doublet was found, and an upper limit on the maximum separation of such a doublet was set at 3 kev. In addition, a search for shorter-range alpha groups was made. The excitation energy ranges of 7.1 to 7.94 Mev and 8.11 to 9.12 Mev in O^{16} were investigated with a negative result.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] A. P. Seed and J. French, Phys. Rev. **88**, 1007 (1952).

D14. Proton Stopping Cross Section of Lithium.* M. BADER, W. A. WENZEL, AND W. WHALING, *Kellogg Radiation Laboratory, California Institute of Technology.*—The energy loss of 450-kev protons passing through a thin film of Li metal has been measured with an electrostatic analyzer and a double-focusing magnetic spectrometer. The film of Li(~250 kev thick) was deposited by vacuum evaporation on a thin Al foil. The thickness of the Li was determined by a quantitative chemical analysis of the Li deposited simultaneously on a tantalum surface of known area. The purity of the deposited Li was determined by a momentum analysis of protons scattered from a thick Li target deposited with the test layer. A negligible surface contamination of O was the principal impurity present. At $E_p=440$ kev the proton stopping cross section is $4.69\pm0.15\ 10^{-15}$ ev-cm². Measurements of relative values determine the stopping cross section at other proton energies. Preliminary results for a similar measurement of Na will be presented.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

THURSDAY MORNING AT 9:00

Student Union Ballroom

(E. FERMI, presiding)

Invited Papers

E1. Origin and Propagation of Air Showers. KURT SITTE, *Syracuse University.* (30 min.)
E2. Transition Phenomena. R. B. BRODE, *University of California, Berkeley.* (20 min.)
E3. Recent Work on Penetrating Showers. W. D. WALKER, *University of Rochester.* (30 min.)
E4. Some Recent Results on *V* Particles. C. D. ANDERSON, *California Institute of Technology.* (30 min.)
E5. Evidence for the General Magnetic Field of the Sun from Cosmic Rays. M. S. VALLARTA, *University of Mexico.* (30 min.)

Contributed Papers

E6. Emulsion Study of a Large Shower. I. The Hard Component. P. S. FREIER AND J. E. NAUGLE, *University of Minnesota.*—A high-energy interaction between a heavy primary and a nucleus of the glass backing of the emulsion has been studied. The core of the shower, a fragment of charge 5, travels 4.72 cm in a single 400-micron G-5 emulsion. The 36 ± 5 shower particles travel a total of 3.9 geometric mean free paths in the emulsion. In this distance 2 nuclear interactions are observed. A third nuclear interaction is observed in a facing emulsion; however, the total path length has not been measured in this plate. All of the shower particles have a grain density corresponding to the plateau value for this emulsion, and relative scattering measurements show that their energies are >40 bev. Two of the secondary interactions have $\lesssim 4$ evaporation particles and show a definite dense and diffuse cone. The third shower has 7 evaporation particles and does not show a separation into a dense and diffuse cone. Analysis of the angular distributions of these showers gives energies from 40–400 bev for these three secondaries. Analysis of the angular distribution of the shower particles gives an energy of about 5×10^4 bev/nucleon for the incident heavy.

E7. Emulsion Study of a Large Shower. II. The Soft Component. J. E. NAUGLE AND P. S. FREIER, *University of Minnesota.*—In the shower described in paper I, 9 pairs of particles have been observed to begin in the emulsion or to enter the emulsion from the glass in the first cm of emulsion and within an angle of 0.1 radian from the shower core. If one assumes that all of the hard particles observed in this same cone are pi mesons and that the pairs originate from the materialization of γ rays from the decay of neutral mesons with zero lifetime, then the ratio of the number of observed pairs to shower particles will give a lower limit for the ratio of neutral meson to charged mesons produced in this event. This ratio is 0.44 ± 0.13. The electrons of these pairs were followed a total of 23.5 cm of emulsion. In this distance 11 tridents (direct pair production by electrons) were observed, giving a mean free path of 2.1 ± 0.7 cm. The theory of Bhabba[1] predicts a value of 12.5 cm for a 50-bev electron and 7.4 cm for a 500-bev electron. Thus, the experimental cross section is larger than that predicted by theory by at least a factor of two.

[1] H. J. Bhabba, Proc. Roy. Soc. (London) **152**, 559 (1935).

E8. Multiple Cores in Air Showers.* OSMAN EL-MOFTY, *University of California, Berkeley (introduced by* ROBERT B. BRODE).—Multiple cores in cosmic-ray air showers are difficult to observe because of the overlapping of the cores. After transition to equilibrium with water, the cores are much smaller and readily identified. Decoherence measurements of the coincidences between pulses in ionization chambers have been made for depths in water from 0 to 3 meters and with separation of the chambers up to 6 meters. The decoherence measurements are consistent with an average air shower at 9000 feet which has about 20 cores within a distance of about 5 meters from the shower's center.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

E9. North-South Observations of the Ratio of Positive to Negative Cosmic-Ray Mesons.* ROBERT B. BRODE, *University of California, Berkeley.*—Observations of the east-west asymmetry in the ratio of positive to negative μ mesons are normally made with the axis of the equipment horizontal and pointing to the magnetic north. Since the magnetic dip is 60° at Berkeley, inclining the axis of the equipment at $\pm30°$ to the horizontal places the plane of measurement approximately parallel or perpendicular to the earth's magnetic field. The east-west asymmetry of the ratio of positive to negative μ mesons observed at an inclination of $\pm30°$ to the horizontal is not essentially different from that observed in the vertical plane. The theory of this asymmetry based on the different path length of positive and negative particles caused by their deflection in the earth's magnetic field indicates that there should be little difference in the ratio of positive to negative μ mesons for inclination of the axis from the horizontal.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

E10. Time Variations in Cosmic-Ray Intensity Underground. MERCEDES M. AGOGINO, *University of New Mexico.*—An experiment to investigate the time variation of cosmic-ray intensity during the solar and sidereal day is being performed at Albuquerque, New Mexico. Two countertube telescopes are located fifty feet underground, one facing east and the other west, both at 45° zenith angles, thus giving them a separation of approximately 7 hours in hour angle. The equipment is rotated through 180° about a vertical axis at the beginning of each hour so that the eastern and western telescopes are interchanged. Analysis of three months' data has given the counting rate for the two directions for each two hours during the sidereal and solar day with a standard deviation of 0.2 percent. Harmonic analysis of the four curves thus obtained does not indicate a clearcut sidereal or solar variation of cosmic-ray intensity greater than may be expected from the quoted statistical error. In each of the four curves a maximum fluctuation of 0.6 percent was found among the 2-hour values. The experiment is being continued.

THURSDAY MORNING AT 9:00

Geology Auditorium

(F. N. FRENKIEL, presiding)

Invited Papers

Division of Fluid Dynamics

F1. Examples of Flow Patterns at and near Mach One. GOTTFRIED GUDERLEY, *Wright Air Development Center.* (40 min.)

F2. Slender Bodies of Revolution at Transonic Speeds. JULIAN D. COLE, *California Institute of Technology.* (40 min.)

F3. Steady and Unsteady Phenomena at Transonic Speeds. ADOLF BUSEMANN, *Langley Aeronautical Laboratory.* (40 min.)

Contributed Papers

F4. Interference of Underwater Sound Caused by Surface Reflection and Upward Refraction. F. H. SANDERS, *Pacific Naval Laboratory.*—Experiments have been carried out at Nodales Channel, British Columbia, on the interference patterns resulting from surface reflection of high audio-frequency sound. Differences in intensity as great as forty decibels have been observed, and some extrema are identifiable at ranges in excess of 2000 yards. Oceanographic conditions in the channel were such as to produce very slight upward refraction. Under such conditions Young[1] has predicted that the time difference between the surface-reflected and the direct-sound paths will pass through a minimum at a certain value of the range. In consequence, interference extrema should exist only if the time difference between the two paths exceeds a certain integral number of half-periods, and two ranges should exist at which an extremum of given order can occur. Experimental observations confirm these predictions. The relation between the observed ranges of the extrema and the other parameters concerned is discussed and compared with Young's theory and with expressions developed by R. W. Stewart.

[1] R. W. Young, J. Acoust. Soc. Am. **19**, 1 (1947).

F5. "Lloyd Mirror" Interference in the Presence of Slight Uniform Refraction. R. W. STEWART, *Pacific Naval Laboratory.*—A ray theory is developed to describe the location of positions of reinforcement and annulment of reflected and direct radiation in the presence of a small velocity gradient. Angles are assumed small enough that two terms of the Maclaurin's series expansion are sufficient to describe the trigonometric functions. Account is taken of the difference in velocity, the curvature of the rays, and the displacement of the point of reflection caused by the refraction. The result is expressed as a series, the first term of which gives the ordinary Lloyd Mirror result for grazing incidence. The second term gives the modification resulting from the nonuniformity of the velocity, and the higher terms give the effects of the curvature of the rays. The first two terms above are shown to yield very similar results to the theory of Young.[1] The theory is applied to the behavior of sound in calm isothermal water.

[1] R. W. Young, J. Acoust. Soc. Am. **19**, 1 (1947).

F6. Thermal Microstructure in the Ocean. W. N. ENGLISH, *Pacific Naval Laboratory.*—A dual-channel ac thermistor bridge and a dc thermistor thermometer have been developed for the study of thermal microstructure in the ocean. Fluctuations as small as 0.01 F° can be recorded. The time constant is about one second. Temperature fluctuations varying from a few hundredths to a few tenths of a degree have been found in all water examined, even in so-called "isothermal" water. Fluctuations were greatest when tidal velocity was least. Transit of temperature structure from one horizontal pair to another can be followed and time to give average velocity of water movement. A high correlation has been observed between rate of change of temperature on a single thermistor and mean gradient measured by a horizontal pair.

F7. Some Correlation Studies of Sound Fluctuations in the Ocean. H. L. GRANT AND R. W. STEWART, *Pacific Naval Laboratory.*—Observations have been made of the fluctuation of sound intensity in the ocean in thoroughly mixed water and in the presence of positive and negative temperature gradients. At a frequency of 18 kc and ranges of about one-half mile, fluctuations of all periods from a fraction of a second to many hours have been detected. The cross correlation between intensities measured at different points in a sound field is found to average nearly zero for vertical separations even as small as two feet. For horizontal separations the cross correlation is quite high at a few feet, but drops to about 0.5 at separations of twenty feet. Not only does the sound fluctuate, but the short-term mean amplitude of the fluctuation varies over wide limits in an apparently random manner.

THURSDAY AFTERNOON AT 2:00

Student Union Ballroom

(H. A. BETHE, presiding)

Invited Papers

G1. Neutron Diffraction by Ferromagnetic and Antiferromagnetic Substances. M. K. WILKINSON, *Oak Ridge National Laboratory.* (30 min.)

G2. Neutron Diffraction by Paramagnetic Substances. W. C. KOEHLER, *Oak Ridge National Laboratory.* (30 min.)

G3. An Experiment to Detect the Free Neutrino. Part I. FREDERICK REINES, *Los Alamos Scientific Laboratory.* (30 min.)

G4. An Experiment to Detect the Free Neutrino. Part II. C. L. COWAN, JR., *Los Alamos Scientific Laboratory.* (30 min.)

Contributed Papers

G5. Background in a Neutrino Experiment.* F. B. HARRISON, C. L. COWAN, JR., AND F. REINES, *Los Alamos Scientific Laboratory, University of California.*—We shall discuss the different types of background encountered in the neutrino experiment[1] described in the two invited papers of this session. Since we require a pair of pulses associated in time, the contribution of random coincidences from single counts (gamma-ray background) can be computed from the counting rate of single pulses and the resolving time. Associated pairs of pulses may, for example, be due to the following causes: μ-meson decay in the scintillator tank; μ-meson capture in the tank and surroundings, giving fast neutrons which give one pulse from proton recoil and another from neutron capture; the N component of cosmic rays, giving fast neutrons from stars in the tank and surroundings; and fast neutrons from the pile. Estimates will be made of how much each of these types of background contribute to the counting rate.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] F. Reines and C. L. Cowan, Jr., Phys. Rev. **90**, 492 (1953).

G6. Liquid Scintillators for Large Volume Detectors.* F. N. HAYES, LLOYD WILLIAMS, C. L. COWAN, JR., AND F. REINES, *Los Alamos Scientific Laboratory, University of California.*—The physical properties required of a solution which is to be used in large volume detectors employing liquid scintillators are: (1) good efficiency as scintillators *per se*, (2) light emission in the frequency range most suitable for detection by the photomultiplier tubes, (3) mean free path for absorption of this light which is large compared to the detector dimensions, and (4), in the event neutrons are to be detected, a high cross section for neutron capture which is associated with good scintillator response. A number of solutions were developed which satisfied the above criteria.[1] These scintillators will be discussed together with the chemistry of their preparation.

* Performed under the auspices of the U. S. Atomic Energy Commission.
[1] Cowan, Reines, Harrison, Anderson, and Hayes, Phys. Rev. **90**, 493 (1953).

G7. Device for Testing Large Numbers of Photomultipliers.* A. BROUSSEAU, C. L. COWAN, JR., AND F. REINES, *Los Alamos Scientific Laboratory, University of California.*—One of the problems met in constructing a detector which utilizes many photomultiplier tubes working in parallel is that of selecting suitable tubes and balancing them to uniform gain. The criteria applied include absence of after pulses, satisfactory gain, stability over a period of time, a fair energy resolution, and low dark current. Selection and balancing is accomplished using a multiple-chamber dark box in which each of ten tubes may be placed under test independently along with their sockets and voltage divider netowrks. A variable low-intensity light source and a NaI crystal and radioactive source are provided for both static and dynamic testing. Currents from the cathodes and anodes may be measured and pulses may be observed with associated amplifier and oscilloscope. A description of applications and results obtained will be given.

* Performed under the auspices of the U. S. Atomic Energy Commission.

G8. Liquid Scintillation Detectors to Accommodate Human Subjects.* [1] R. L. SCHUCH, E. C. ANDERSON, C. L. COWAN, JR., F. B. HARRISON, F. N. HAYES, AND F. REINES, *Los Alamos Scientific Laboratory, University of California.*—A steel insert 20 inches in diameter, 30 inches high with a 0.015-inch wall was placed in a detector in the shape of a circular cylinder measuring 28 inches in diameter and 30 inches high. The 4-inch thick annular region was filled with a scintillator solution of toluene-terphenyl-alpha naphthylphenyloxazole. Forty-five RCA 5819 photomultipliers, connected in parallel were placed around the cylinder walls. Energy gates were 0.3 to 2.0 Mev. The detector was shielded by 4 inches of lead except for the top of the insert which was left open. K^{40} in a test phantom gave a counting efficiency of 14 percent, corresponding to a counting rate of 78 per second from the K^{40} in a 70-kg man. Measured values using human subjects ranged from 30 to 80 counts per second above a background of 837 ± 6 per second. 0.2μC of Ra shielded by a human subject gave 1133 counts per second or about 15 percent efficiency, indicating the possibility of detection of Ra well below presently established tolerance levels.

* Performed under the auspices of the U. S. Atomic Energy Commission.
[1] To be published in Nature.

G9. Some Properties of Large Liquid Scintillation Detectors.* E. C. ANDERSON, C. L. COWAN, JR., AND F. REINES, *Los Alamos Scientific Laboratory, University of California.*—Preliminary to the experiment to detect the free neutrino, an investigation of the general properties of large liquid scintillation detectors was carried out.[1] A pilot model of 50 liters volume (40 cm diameter by 40 cm deep) using 32 photomultipliers was first operated in October, 1952. The signal output from gamma rays was estimated to be about 85 equivalent electrons per Mev from the photocathodes with all tubes in parallel and a scintillator of terphenyl plus alpha-naphthyl phenyl oxazole in toluene. The energy resolution was about 25 percent (half-width at half-height) at one Mev. The full-scale detector, a cylinder of 300 liters volume, using 90 photomultipliers had an energy resolution of about 10 percent at one Mev. The broadening in the smaller detector is due to end effects since in that case the gammas are not completely degraded by multiple Compton scattering before escaping. By adding cadmium propionate to the solution and observing delayed coincident pulses, a very sensitive detector was obtained for events involving a neutron, produced in prompt or delayed coincidence with a charged particle.

* Performed under the auspices of the U. S. Atomic Energy Commission.
[1] Cowan, Reines, Harrison, Anderson, and Hayes, Phys. Rev. **90**, 493 (1953).

THURSDAY AFTERNOON AT 4:15

Room 101, Mitchell Hall

(J. KAPLAN, presiding)

Contributed Papers

H1. Ionization Loss in Nuclear Emulsions.* JOHN R. FLEMING AND J. J. LORD, *University of Washington.*—A 400-micron Ilford G5 plate was exposed successively to 227, 122, 77, and 33-Mev negative pions and also to slow negative muons from the Chicago cyclotron. The plate kindly furnished by Professor Schein and Professor Anderson was rotated 45° after each exposure so that the tracks of different energy could be distinguished and in addition so that track grain and blob densities could be made over a restricted portion of a single plate. Correcting for the average track length in the emulsion, the grain densities for pions of 31, 81, 120, 224 Mev and the decay electrons from muons were, respectively, 75.28, 51.61, 47.11, 36.91, 42.06, per 100μ, where each average value is based on more than 11 000 grains. The corresponding blob densities over the same tracks were, respectively, 44.49, 35.94, 34.44, 27.08, 30.72 per 100μ. Assuming the grain densities to be proportional to the energy loss for exchanges less than 5 kv, the above measured values agree well with the calculation of Sternheimer based on the Fermi, Halpern-Hall type considerations. Theory gives a 14 percent difference between plateau and minimum ionization in excellent agreement with the measured 12.0±percent between 224-Mev pions and muon decay electrons.

* Supported in part by the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

H2. Ionization of Relstivistic Cosmic-Ray μ Mesons.* H. R. SNODGRASS, *University of California, Berkeley.*—Proportional counters filled with argon and range-interval defining Geiger counters were employed to study the variation of ionization with momentum for μ mesons. The ionization values were analyzed to yield the most probable ionization and the average ionization for four momentum intervals: 0.25 to 0.63 to 1.17 to 2.38 to >2.38 Bev/cy. The distribution of the ionizations was also examined for the four momentum intervals. The equipment was calibrated by normalization to the minimum ionizing momentum group. The values of the most probable ionization and the average ionization showed a consistent rise with increasing momentum, indicating that the theoretical logarithmic rise is valid for μ-meson momenta of up to 5 Bev/cy. The distribution of the ionization values was compared with the Landau[1] and the Blunck-Leisegang[2] theories. The observed frequency of small ionization values was much larger than predicted by Landau and more nearly in agreement with the theory of Blunck-Leisegang.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] L. Landau, J. Phys. U.S.S.R. **8**, 201 (1944).
[2] O. Blunck and S. Leisegang, Z. Physik **128**, 500 (1950).

H3. Cascade Decay of *V* Particles. I.* C. D. ANDERSON, E. W. COWAN, R. B. LEIGHTON, AND V. A. J. VAN LINT, *California Institute of Technology.*—Three cloud-chamber exposures of a charged V particle apparently decaying into a V^0 particle in a magnetic field have been taken at Pasadena. In a similar previous case,[1] the V^0 particle could not be classified as to type. The new data provide strong evidence for the reality of cascade decays, and identify the V^0 particle as a V_1^0 (decaying into $p+\pi^-$). In all three cases the parent charged V particle is negative (as in the case of reference 1), and emits a negative π or μ meson. The above conclusions are based on measurements of (1) relative positions of decay points in the cloud chamber, (2) "coplanarity," (3) momenta and ionizations of secondary particles, and (4) position and number of nuclear events in which V particles might originate. In all three cases the line of flight of the V^0 particle makes a much smaller angle with the positive decay product than with the negative, $\theta_+/\theta_-=0.16$, 0.22, and 0.41, thus indicating the decay products of the V^0 particle to have unequal masses.

* Supported in part by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Armenteros, Barker, Butler, Cachon and York, Phil. Mag. **43**, 597 (1952).

H4. Cascade Decay of *V* Particles. II.* E. W. COWAN, C. D. ANDERSON, R. B. LEIGHTON, AND V. A. J. VAN LINT, *California Institute of Technology.*—In one of the three cases of the preceding abstract, the positive particle in the V^0 decay has a momentum of 880±100 Mev/cy, and ionization 1.7 times minimum, determining by counting droplets. This is consistent with a proton but not with a π meson, indicating the V^0 particle is not of the type that decays into two π mesons. The Q value is 39±10 Mev assuming $\pi-p$ decay, and 36±10 Mev assuming $\pi-\pi$ decay. The latter value is much lower than the usual range of values for $\pi-\pi$ decay. It can further be shown, on the assumption of a two-body decay, using only the momenta and included angle of the two decay particles, that the observed angular asymmetry about the line of flight of the neutral particle is too great to correspond to a decay into two π mesons. The charged secondary of the V^- decay has a momentum of 64±10 Mev/cy, an estimated ionization of 2–4 times minimum, and is therefore either a π or μ meson. On the assumption that the V^- particle decays into a V_1^0 and a π or μ meson, the best Q value, obtained from 2 of the 3 cases, is 60±15 Mev for a π meson and 62±15 Mev for a μ meson secondary. The calculated mass-values of the charged V particle on these two assumptions are 2570±30 and 2510 ±30m_e, respectively.

* Supported in part by the joint program of the U. S. Office of Naval Research and the Atomic Energy Commission.

H5. Charged and Neutral *V* Particles.* W. B. FRETTER AND E. W. FRIESEN, *University of California, Berkeley.*—Charged and neutral V particles observed in a 40-cm ×50-cm cloud chamber at sea level will be described. The chamber is filled with helium which allows ionization measurements to be made by drop counting. Curvature measurements in the average field of 8000 gauss appear to be reliable to 0.01 m^{-1}. The precision measurements of curvatures and angles are corrected for the effects of magnification, magnetic field variation, and gas displacement. Some of the observed V^0 particles are consistent with the V_1^0 ($p+\pi$, $Q=37$ Mev) and the V_4^0 ($\pi+\pi$, $Q=214$ Mev). Several of the particles, however, appear to be inconsistent with these interpretations. Most of the charged V particles can be interpreted as kappa particles.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

H6. Cloud-Chamber Observation of the Decay of a τ Meson.* V. A. J. VAN LINT AND G. H. TRILLING, *California Institute of Technology.*—In a new apparatus at Pasadena consisting of a vertical array of four cloud chambers in a field of 8000 gauss, the decay in flight of a τ meson has been observed. The event is of interest because the tracks of the

decay products are long (35, 18, 18 cm) and lend themselves to accurate momentum measurement (188±6; 127±10; 103±8 Mev/cy). The track of the τ meson is short and its momentum not directly measurable. Within experimental error the direction of the τ meson coincides with the vector sum of the momenta of the charged decay products, thus indicating the absence of neutral secondaries, in agreement with previous results. The τ meson is negative; in the only other case in which the sign of charge of a τ meson could be determined, it was found to be positive.[1] The specific ionization and curvature of the tracks are consistent with the assumption of π meson secondaries. On this assumption the energy release of the τ meson is 70±3 Mev corresponding to a mass of $964\pm6m_e$. The τ meson was not observed to originate in a nuclear event, thus there is no evidence here as to its mode of production.

* Supported in part by the joint program of the U. S. Office of Naval Research and the Atomic Energy Commission.
[1] R. B. Leighton and S. D. Wanlass, Phys. Rev. **86**, 426 (1952).

H7. Cross Section for the Production of Penetrating Cosmic-Ray Showers in Oxygen.* JAMES F. KENNEY AND VICTOR H. REGENER, *University of New Mexico.*—An experiment is being performed at Capillo Peak, New Mexico at an altitude of 2800 m to determine the cross section for penetrating shower production by neutral *N* rays in oxygen. The collision length for this event is measured in ethyl alcohol and in oxalic acid, and the oxygen cross section is obtained by the method of differences. The value of this cross section seems to fall fairly close to that predicted by the geometric nuclear model. With further improvement of the statistical accuracy, the data from this experiment will be combined with those obtained from previous experiments with similar equipment using light and heavy water.[1] This will lead to an evaluation of the nuclear cross section for the production of penetrating showers in carbon, hydrogen, and deuterium.

* Supported in part by the National Science Foundation.
[1] G. W. Rollosson, Phys. Rev. **87**, 71 (1952); Froman, Kenney, and Regener, Phys. Rev. (to be published).

H8. Cross Section for Production of Penetrating Cosmic-Ray Showers. ROY THOMAS, *University of New Mexico.*—Highly energetic neutrons interacting with nuclei create showers of energetic protons, neutrons, π-mesons, etc. The usual theoretical approach is to assume that at very high energies the nucleons in a nucleus may be considered as free. One then calculates the cross section as a function of the nuclear radius and a collision mean-free path for an incident neutron in nuclear matter. The suggestion made in this paper is to consider the opposite view. We define an interaction volume directly proportional to the nuclear binding energy. Any incident neutron of sufficient energy which penetrates this interaction volume will initiate a penetrating shower. The cross section is proportional to the two-thirds power of the nuclear binding energy. Transparency of light nuclei to penetrating shower production thus follows with the introduction of only one parameter to be fitted to the experimental data. With any other theory one needs at least two parameters to explain the transparency of light nuclei.

THURSDAY AFTERNOON AT 4:15

Room 102, Mitchell Hall

(C. D. ANDERSON, presiding)

Contributed Papers

I1. Photoproduction of Positive Mesons from Hydrogen: Magnetic Spectrometer Method. R. L. WALKER, J. G. TEASDALE, AND V. Z. PETERSON, *California Institute of Technology.*—The differential cross section for photoproduction of positive pions in hydrogen has been measured at angles from 40° to 150° in the center-of-mass system, for photon energies from 220 to 475 Mev. An attempt will be made to extend this range of angles. Mesons produced by 500-Mev bremsstrahlung in a high-pressure gas target are analyzed by a large magnet with wedge-shaped pole pieces and counted by two large liquid scintillation counters in coincidence, placed at the focal point of the magnet. A typical arrangement of counters and magnet accepts mesons emitted in a solid angle of 0.01 steradians with a momentum resolution of nine percent. This corresponds to a spread in incident photon energies of 10 Mev in the low-energy region and 50 Mev at the high-energy end. Range measurements of the analyzed particles show that most of them are π mesons but that some μ mesons are counted as expected. The flight path of the mesons is long, and corrections for $\pi-\mu$ decay amount to a factor 1.2 to 1.8, depending on the meson energy. Results obtained so far are reported in the third abstract of this series.

I2. Angular Distribution of Positive Photomesons from Hydrogen: Counter Telescope Method. A. V. TOLLESTRUP, J. C. KECK, AND R. M. WORLOCK, *California Institute of Technology.*—The angular distribution and excitation curve for the process $\gamma+p\rightarrow\pi^++n$ have been obtained for gamma-ray energies between 225 and 475 Mev. This experiment was done simultaneously with the accompanying magnetic spectrometer experiment, but it is independent of that experiment except for the common beam monitoring equipment. The mesons from the high-pressure, low-temperature hydrogen target were identified by measuring their ionization for a fixed residual range with a scintillation counter telescope consisting of 3 counters in coincidence and a fourth in anticoincidence. The meson energy, as deduced from its range in copper, and its angle determine the photon energy. The energy resolution of the counter telescope was determined by the amount of absorber between the last two counters. This was chosen so that the spread of meson energies accepted was 10 Mev which corresponded typically to a 20-Mev spread in photon energy. The background corrections due to mesons from the walls of the hydrogen target and to accidental coincidences in the telescope are about 10 percent, and the statistical errors are in general about 5 percent. Excitation curves were run at angles corresponding to angles of 50°, 70°, 90°, 110°, 130°, and 150° in the c.m. system, and from smoothed curves the angular distribution was obtained. The results are discussed in the last paper of this series.

I3. Photoproduction of Positive Mesons from Hydrogen: Results. R. F. BACHER, J. C. KECK, V. Z. PETERSON, J. G. TEASDALE, A. V. TOLLESTRUP, R. L. WALKER, AND R. M. WORLOCK, *California Institute of Technology.*—The center-of-mass differential cross section for photoproduction of positive pions from hydrogen has been measured by the methods described in the two previous abstracts, in the angular range 40° to 150°,

for photons from 220 to 475 Mev. (Photon energies refer to the Laboratory System.) Results obtained by the two methods are in essential agreement. At 90°, $d\sigma/d\omega$ has a maximum of 2.7×10^{-29} cm²/sterad near 280 Mev and falls by a factor 5 at 450 Mev. The maximum in the excitation curve is even more pronounced at larger angles, but less pronounced at smaller ones. At 40° (c.m.) the peak occurs near 350 Mev, and at 450 Mev the cross section has decreased only to 0.7 the peak value. Angular distributions in the center-of-mass system show a marked assymetry about 90°, which changes character from low energy to high. Below 325 Mev, there is a backward maximum, whereas above 375 Mev, there is a forward maximum. The total cross section reaches a maximum near 290 Mev and decreases by about a factor 3 at 450 Mev. The results below 300 Mev agree with the data already reported from Berkeley and Cornell.

I4. Yield of Mo^{99} from Fission of U^{235} and U^{238}.† JAMES TERRELL, W. E. SCOTT,* J. S. GILMORE, AND C. O. MINKKINEN, *University of California, Los Alamos Scientific Laboratory.*—A double fission chamber was used to measure the fissions produced in one-inch diameter, 25-gram disks of U^{235} and normal uranium. Thin foils of the same material, mounted on either side of the disks, were fission counted during irradiation. Corrections were applied for counting losses and the effects of fission-produced and scattered neutrons from the disks. Fast neutrons were produced by P−T, D−D, and D−T reactions; the thermal neutron source was the Los Alamos Homogeneous Reactor. The yield of Mo^{99} was determined by chemical separation of molybdenum from the disks, followed by absolute beta counting. Absolute calibration was done with the aid of John P. Balagna of this laboratory. Results obtained so far (Mo^{99} atoms per fission) are tabulated here, with estimated standard deviations. The thermal value

	Thermal	0.95	1.55	4.85	14.2	(Mev)
U^{235}	6.14±0.16	6.10±0.16		5.45±0.16		(percent)
U			6.19±0.15	6.45±0.16	5.68±0.14	(percent)

and the decrease with increasing energy are consistent with other determinations.[1]

† Work done under the auspices of the U. S. Atomic Energy Commission.
* Major, United States Air Force, now at Kirtland Air Force Base, New Mexico.
[1] *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), National Nuclear Energy Series, Div. IV, Vol. 9.

I5. The Energy Distribution of Slowed Fission Fragments.* J. A. NORTHROP AND J. E. BROLLEY, JR., *University of California, Los Alamos Scientific Laboratory.*—A conventional gridded ion chamber has been used to measure the energy distribution of fission fragments slowed by a UO_2 absorber. A 20μ g/cm² layer of $U^{235}O_2$ 2 in. in diameter vacuum evaporated on a 0.030-in. tantalum backing and placed in a beam of thermal neutrons from the Los Alamos Homogeneous Reactor provided the source of fission fragments. These were slowed by a uniform layer of $U^{238}O_2$ evaporated directly over the first. A series of six such foils, each having a 20μ g/cm² $U^{235}O_2$ base layer, but $U^{238}O_2$ layers varying from 0 to 1 mg/cm², were mounted on a wheel inside the ion chamber in such a way that they could be successively rotated into the neutron beam. The high uniformity of these foils made it possible to obtain fission curves in which the ratio of the light peak to the valley between is 14:1, even after slowing the fragments in the UO_2. There is some evidence for complex structure on the high-energy side of the heavy particle peak of the unslowed fragments. Preliminary results for the initial energy loss of fission fragments in UO_2 is 0.020 Mev-cm²/μ g (light fragment), 0.017 Mev-cm²/μ g (heavy fragment).

* Work done under the auspices of the U. S. Atomic Energy Commission.

I6. Velocity Distributions of Slowed Fission Fragments. H. W. SCHMITT AND R. B. LEACHMAN, *University of California, Los Alamos Scientific Laboratory.*—The velocity distributions of slowed fission fragments have been measured by a method similar to that used by Leachman[1] in the determination of the velocity distributions of fission fragments from the thermal fission of U^{233}, U^{235}, and Pu^{239}. In our measurements, fragments from the thermal fission of U^{235} are slowed by perpendicular passage through thin nickel or aluminum absorbers as follows: 1.1 mg/cm² Ni, 1.1 mg/cm² Al, 1.4 mg/cm² Al. The slowed-fragment velocity distributions show a definite irregularity in the heavy peak but a less pronounced irregularity in the light peak. This difference in irregularities is at least partially explained by the better resolution in the measurements of the heavy fragment groups. These irregularities are in agreement with the fine structure in the mass yield of fission as found by Glendenin *et al.*[2] The fact that the irregularities are more prominent in the distributions obtained with more absorbing foils can be explained in terms of shell effects and processes of energy loss of fission fragments in matter.

[1] R. B. Leachman, Phys. Rev. **87**, 444 (1952).
[2] Glendenin, Steinberg, Inghram, and Hess, Phys. Rev. **84**, 860 (1951).

THURSDAY EVENING AT 8:00

Student Union Ballroom

(V. H. REGENER, presiding)

Public Lecture

J1. Developments in High-Energy Physics. E. FERMI, *University of Chicago.*

FRIDAY MORNING AT 9:00

Student Union Ballroom

(N. E. BRADBURY, presiding)

Invited Papers

K1. Beta Spectra. L. M. LANGER, *Indiana University.* (30 min.)

K2. Nuclear Isomers. M. GOLDHABER, *Brookhaven National Laboratory.* (30 min.)

K3. Excitation of Heavy Nuclei by the Electric Field of Low-Energy Protons. CLYDE MCCLELLAND, *Massachusetts Institute of Technology.* (20 min.)

K4. Light Particle Reactions. R. F. TASCHEK, *Los Alamos Scientific Laboratory.* (30 min.)

K5. Cross Sections of Proton Reactions. W. A. FOWLER, *California Institute of Technology.* (30 min.)

Contributed Papers

K6. Deuteron Disintegration by 9.7-Mev Protons.* JUANITA H. GAMMEL, *University of California, Los Alamos Scientific Laboratory.*—The angular distribution of protons emitted in inelastic $p-d$ scattering has been measured between 25° and 90° in the laboratory system. These results are a by-product of a $p-d$ elastic scattering experiment[1] performed with a multiplate camera and the 9.7-Mev proton beam from the Berkeley cyclotron. A total of 1085 inelastically scattered protons from five runs were observed. The cross section obtained for emission of protons of energy >1 Mev is 104 ± 20 millibarns (the deuteron disintegration cross section is one-half of the total cross section for emission of protons). The angular distribution is as follows: 25°, 73 ± 15 mb; 30°, 53 ± 11 mb; 40°, 31 ± 6 mb; 50°, 19 ± 4 mb; 60°, 10 ± 2 mb; 70°, 4 ± 1 mb; 80°, 1 ± 0.5 mb; 90°, 0 ± 0.5 mb. Additional work is now in progress to determine the distribution in energy of the disintegration protons at 37.5°. A theoretical interpretation of available data on inelastic $p-d$ and $n-d$ scattering will be presented by R. M. Frank and J. L. Gammel.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] Allred, Armstrong, Bondelid, and Rosen, Phys. Rev. **88**, 433 (1952).

K7. Inelastic Scattering of Protons and Neutrons by Deuterons. R. M. FRANK AND J. L. GAMMEL, *University of California, Los Alamos Scientific Laboratory.*—By assuming that the range of nuclear forces is small compared to the size of the deuteron and the wavelength of the incoming particle ("zero range" approximation) and using something like the impulse approximation, a connection between the cross sections for elastic and inelastic $p-d$ or $n-d$ scattering is derived. The results of this simple theory are compared with available experimental data, and the agreement between the two is much better than the crude assumptions of the theory merit. An interesting consequence of the theory is that the connection between the elastic and inelastic scattering cross sections is independent of the properties of the two-body forces. The elastic scattering cross section depends hardly at all on the exchange properties of the two-body $n-p$ potential (provided it gives the binding energy of the deuteron correctly) and the $n-n$ potential,[1] and the connection suggests that the same is true of the inelastic scattering cross section. This is in disagreement with more elaborate calculations of Bransden and Burhop.[2] Another consequence is that the ratio of the cross section for absorption of neutrons from a partial wave of angular momentum l by inelastic scattering to the cross section for elastic scattering for the same partial wave is independent of l. This makes it possible to calculate the effect of the inelastic scattering on the elastic scattering in a simple way, as explained in the following paper.

[1] R. S. Christian and J. L. Gammel, Phys. Rev. **91**, 100 (1953).
[2] B. H. Bransden and E. H. S. Burhop, Proc. Phys. Soc. (London) **A63**, 1337 (1950).

K8. Elastic Scattering of Protons and Neutrons by Deuterons at High Energy. J. L. GAMMEL, *University of California, Los Alamos Scientific Laboratory.*—The "phase shifts" which appear in an analysis of high-energy $n-d$ or $p-d$ elastic scattering must be complex numbers, since inelastic scattering also occurs. A modification of Born's approximation is presented which takes account of the effect of the inelastic scattering on the elastic scattering. From it complex phase shifts are derived which satisfy requirements imposed on them by the condition that particles be conserved. These are substituted into the exact scattering formula for $n-d$ inelastic scattering, so that the calculation is at least a valid phase shift analysis of the data, and in addition contains an effort to take account of the effect of the inelastic scattering. Even when the worst properties of the three-dimensional Born approximation are avoided by substituting phase shifts calculated in Born approximation into the exact scattering formula, calculations of the angular distribution for elastic scattering give a cross section for backward scattering which is much too large. A recent calculation suggests that this is due in part to the neglect of tensor forces. However, the present calculation with central forces only is in agreement with the experiments. It is not maintained that the effects of tensor forces are in fact negligible but only that they can be reproduced by the same "equivalent" central potential which reproduces their effects in high energy $n-p$ scattering. It is shown that at low energies (14 Mev) neglect of the effect of inelastic scattering on the elastic scattering is justified.

K9. Small Angle Cross Sections for the Scattering of Protons by Tritons. M. E. ENNIS AND A. HEMMENDINGER, *University of California, Los Alamos Scientific Laboratory.*—Measurements of the differential elastic scattering cross sections of tritons for protons have been made using a 14-inch inside diameter scattering chamber with a proportional counter movable from 140° on one side of the forward direction of the beam through the zero position to 90° on the other. These cross sections were determined as a function of laboratory angle from the scattered proton yields for angles from 15° to 60° and from the yields of the recoil tritons for angles from 62.8° to 136.8°. Measurements were made at eleven energies from 0.990 Mev to 2.548 Mev, with five of these clustered near the 1.019-Mev threshold of the $T(p, n)He^3$ reaction. Comparison with the cross sections reported by Hemmendinger *et al.*[1] shows the values obtained in the present work to be larger in the angular range near 150° in the center-of-mass system and smaller elsewhere. Agreement with the results of Claassen *et al.*[2] is good for the two energies for which comparable data are available.

[1] Hemmendinger, Jarvis, and Taschek, Phys. Rev. **76**, 1137 (1949).
[2] Claassen, Brown, Freier, and Stratton, Phys. Rev. **82**, 589 (1951).

K10. Scattering of Fast Neutrons by He^4.* JOHN D. SEAGRAVE, *University of California, Los Alamos Scientific Laboratory.*—Angular distributions of neutrons elastically scattered by He^4 have been measured for neutron energies of 2.61, 4.53, 5.54, 6.50, and 14.2 Mev. The technique used was similar to that of Adair.[1] The pulse-height distribution of the recoiling alphas was observed in a large proportional counter filled with a mixture of helium and krypton; however, a neutron collimator was employed and the neutron beam was transverse to the axis of the counter, thus minimizing the wall effect, for which a correction was applied. All five distributions are similar and are characterized by strong scattering of the neutrons in the forward direction, a minimum for neutrons scattered near 120° in the center-of-mass system, and a smaller peak for backscattering. The ratio of differential cross sections $\sigma_{back}/\sigma_{min}$ increases smoothly with energy over the range studied. These distributions are in agreement with the n-He^4 distributions predicted from the phase-shift analysis of p-He^4 scattering by Dodder and Gammel[2] but seem to be in disagreement with the results of Huber and Baldinger.[3]

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] R. K. Adair, Phys. Rev. **86**, 155 (1952).

[2] D. C. Dodder and J. L. Gammel, Phys. Rev. **88**, 520 (1952), and private communication.

[3] P. Huber and E. Baldinger, Helv. Phys. Acta **25**, 435 (1952).

FRIDAY MORNING AT 9:00

Geology Auditorium

(J. KAPLAN, presiding)

Invited Papers

L1. Atmospheric Propagation of Sounds from Explosions. E. F. COX, *Sandia Corporation.* (30 min.)

L2. High-Altitude Winds by Meteor-Train Photography. WILLIAM LILLER AND F. L. WHIPPLE, *Harvard College Observatory.* (30 min.)

L3. Thunderstorm Electricity. E. J. WORKMAN, *New Mexico Institute of Mining and Technology.* (30 min.)

L4. Measurements of World-Wide Electrical Effects. R. E. HOLZER, *University of California, Los Angeles.* (30 min.)

Contributed Papers

L5. The Automatic Recording of the Zodiacal Light.* VICTOR H. REGENER, *University of New Mexico.*—Automatic recording equipment for the Zodiacal Light has been put into operation at the Capillo Peak Observatory. A parabolic mirror of diameter 60 inches is positioned by means of a servo system in such a manner as to scan the night sky in equatorial coordinates. The output of a photomultiplier tube mounted at the focus of the mirror governs, through an amplifier of special design, the pattern executed by the spot of an oscilloscope tube in 18 discrete steps. At the same time, a lens of short focal length is made to travel in a plane parallel to the surface of a film in synchronism with the 60-inch mirror and in such a way as to project an image of the oscilloscope screen onto the surface of the film. A map of the night sky in terms of light intensity is thus automatically obtained. Isophotes can be plotted directly into such a map by connecting points where the amplifier changes from one step to the next because of a passing of the light intensity through a certain value.

* Supported, in part, by Air Force Cambridge Research Center.

L6. Procedure for the Evaluation of Automatic Zodiacal Light Recordings. RICHARD J. RUNGE, *University of New Mexico.*—The automatic records of the intensity of the light of the night sky obtained at the Capillo Peak Observatory give uncorrected intensities in terms of right ascension and declination. This paper discusses the procedure used in applying corrections for background and for extinction. The maps which are automatically drawn by the instrument are evaluated first for background intensity not caused by the zodiacal light. Extinction corrections are then applied on the basis of star intensities observed with the same instrument during the same night. Thus, extraterrestrial intensity records are obtained for the zodiacal light in terms of stellar magnitudes per square degree.

L7. The Focusing of Short Electromagnetic Waves by Means of the Fresnel Half-Period Zone Plate. H. GEORGE OLTMAN, *University of New Mexico.*—The theory of the Fresnel Half-Period Zone Plate is applied to the construction of a highly directional focusing device, or "lens," for short electromagnetic waves. Two models have been constructed for a wavelength of 11 cm, one with two obstructed zones and a maximum diameter of 4.2 meters, the other with five obstructed zones and a maximum diameter of 4.8 meters. These zones were made of wire mesh. The characteristics of the two models are: Power gain 25 and 56, angular definition of the image of a point source (to the half-power point) 0.6°, and useful total angular width of the field approximately 50°. A device of this kind should find applications in radio-astronomical work.

L8. Ion Density in the *E*-Layer by the Use of a Sounding Rocket.* L. B. LINFORD, O. C. HAYCOCK, J. I. SWIGART, C. L. ALLEY, AND C. D. WESTLUND, *University of Utah,* AND J. R. LIEN, *Air Force Cambridge Research Center.*—A successful ionosphere experiment has been carried out with an Aerobee rocket. Transmission times for seven different frequencies from 0.4 to 1.4 megacycles above the critical frequency were compared with the transmission time for 470 megacycles. The zenith was 84 miles. Excellent dispersion curves were obtained. From the data, the index of refraction, the ion density, and the collision frequency can be calculated through the *E*-layer.

* This work was carried out under Contract No. AF 19(604)-384 with the Geophysics Research Division of the Air Force Cambridge Research Center.

FRIDAY AFTERNOON AT 2:00

Student Union Ballroom

M1. Panel Discussion on Artificial Mesons, led by E. FERMI. Some of the panel members are J. LEPORE, FRANK CRAWFORD, R. F. CHRISTY, R. L. WALKER, AND H. A. BETHE. (2 hours)

FRIDAY AFTERNOON AT 4:15

Room 101, Mitchell Hall

(M. GOLDHABER, presiding)

Contributed Papers

N1. Contribution of Collective Motion to the Magnetic Moments of Heavy Nuclei. KENNETH W. FORD, *Princeton University and Los Alamos Scientific Laboratory.*—The coupling of the motion of individual nucleons to the nuclear surface oscillations affects the nuclear magnetic moment in two ways: (1) The surface interaction provides a mechanism of configuration interaction and mixes different particle states. (2) The bulk motion of nuclear matter represented by the surface waves contributes directly to the moment. These two effects have been calculated in the limits of weak and strong coupling of nucleon to nuclear surface.[1] The predicted deviations from the Schmidt lines are qualitatively alike in the two limits, quantitatively greater for strong coupling, but not great enough to explain the largest observed deviations. From the $l+\frac{1}{2}$ Schmidt line, the direction of deviations and qualitative differences among nuclei in magnitude of deviation are explained. From the $l-\frac{1}{2}$ Schmidt line, the predicted deviations are small and largely opposite in direction to the observed deviations. The calculations afford additional indirect evidence for a diminished anomalous moment of the nucleon in the presence of nuclear matter.

[1] Second effect previously calculated by Foldy and Milford, Phys. Rev. **80**, 751 (1950), Bohr, Phys. Rev. **81**, 134 (1951), and Davidson and Feenberg, Phys. Rev. **89**, 856 (1953).

N2. A New First Excited State of an Even-Even Nucleus Kr^{80}.* GERTRUDE S. GOLDHABER AND MICHAEL MCKEOWN, *Brookhaven National Laboratory.*—The 18-min isomer Br^{80} is shown to emit γ rays of 620-kev energy which follow a low-intensity (3–5 percent) β-ray branch. Beta-gamma coincidences are observed, indicating that the gamma transition takes place in Kr^{80}. No γ transitions were found to follow the positron or K-capture branch. The intensity observed is compatible with a spin and parity assignment 1+ for the ground state of Br^{80}, while the 620-kev state in Kr^{80} is probably 2+. The energy observed fits well into the pattern for the energy of the first excited state of even-even nuclei.[1,2]

* Work carried out under the auspices of the U. S. Atomic Energy Commission.
[1] P. Preiswerk and P. Stähelin, Helv. Phys. Acta **24**, 623 (1952).
[2] G. Scharff-Goldhaber, Phys. Rev. **90**, 587 (1953).

N3. Energy Levels in Hafnium Isotopes.* D. J. HUGHES, W. Y. KATO, AND J. S. LEVIN, *Brookhaven National Laboratory.*—The nuclear energy levels in the hafnium isotopes at excitation energy just above neutron binding energy have been measured by observation of neutron resonances in normal hafnium and several of its separated isotopes. Total cross sections were measured with the Brookhaven fast chopper in the neutron energy region 0–100 ev; above 100 ev the resolution is insufficient to resolve the resonances. For most of the resonance measurements the samples of partially enriched isotopes used were of the order of 200 mg. Below 100 ev only one resonance occurs in Hf^{178} and one in Hf^{180}, the balance of the resonances found in normal hafnium (about 25 below 100 ev) being assigned to Hf^{177} or Hf^{179}. Thus, although Hf^{174} and Hf^{176} have not been measured as yet, none of the resonances observed in normal hafnium are in these isotopes. In several cases, apparently single resonances in normal hafnium have been shown to be superpositions of levels in Hf^{177} and Hf^{179} by their strength and slight energy shifts in the enriched isotope samples.

* Work carried out under contract with the U. S. Atomic Energy Commission.

N4. Bound State Corrections in the Two-Body System. THOMAS FULTON, *Harvard University,* AND ROBERT KARPLUS, *University of California Radiation Laboratory, Berkeley.*—Available expressions[1–3] for two-body equations contain an interaction kernel which treats particles in intermediate states as free. In situations where the binding is important, such as the calculation of low-energy electrodynamic corrections, a more accurate treatment is necessary. A satisfactory formalism has been developed for systems in which an instantaneous interaction is responsible for the binding. The procedure may then be used to evaluate the effects of small retarded perturbations. It consists of summing those binding interactions which occur during the retarded perturbations and which never should have been expanded as "small" effects. The result is expressed in terms of the two-body Green's function of the instantaneous interacting system. This function occurs to describe the propagation of the two particles in the intermediate state. Applications to electrodynamic systems, to which the method is particularly suitable, are in progress.

[1] J. Schwinger, Proc. Natl. Acad. Sci. U. S. **37**, 452, 455 (1951).
[2] H. A. Bethe and E. E. Salpeter, Phys. Rev. **84**, 350 (1951).
[3] R. Karplus and A. Klein, Phys. Rev. **87**, 848 (1952).

N5. An *R*-Matrix Formulation of the Statistical Theory of Nuclear Reactions.* R. G. THOMAS, *University of California, Los Alamos Scientific Laboratory.*—By means of the Wigner-Teichmann channel elimination procedure, an exact expression is obtained for $f_e(E)^{-1}$, the inverse logarithmic derivative for the entrance channel e, in terms of the E_λ, the γ_λ of all channels, the shift factors, and the penetration factors P_r of the reaction channels r. The cross section for compound nucleus formation is determined by the real and imaginary parts of this quantity. If the off-diagonal absorption widths $\Gamma_{\lambda\mu}=2\Sigma_r P_r\gamma_{\lambda r}\gamma_{\mu r}$, comprising individual terms which are as likely to be positive as negative, are negligible compared with the diagonal absorption widths $\Gamma_{\lambda\lambda}$, and if $\Gamma_{\lambda\lambda}\gg D$, D being the level spacing, then the expression for $f_e(E)^{-1}$ reduces

to the value of the ee component of the R matrix at the complex energy $E+\frac{1}{2}i(\Gamma_{\lambda\lambda})_{Av}$. The Feshbach-Weisskopf schematic theory assumption that $f_e=-iK$ follows by neglecting the real part of this component and by using the $\langle\gamma_{\lambda e}^2\rangle_{Av}=D/\pi K$ relation for evaluation of the imaginary part. In their more recent theory, which involves the consideration of a complex square well potential, the real part of this component is important. It will also be shown that if the $\Gamma_{\lambda\mu}$ are negligible, the compound nucleus will decay in a manner which is independent of how it is formed.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

N6. A State in C^{12} Predicted from Astrophysical Evidence.* F. HOYLE, *Cambridge University* AND D. N. F. DUNBAR, W. A. WENZEL, AND W. WHALING, *Kellogg Radiation Laboratory, California Institute of Technology.*—It is assumed that oxygen and carbon are produced in stars that have largely exhausted their central hydrogen by the reactions: $2He^4\rightarrow Be^8$; $Be^8+He^4\rightarrow C^{12}$; $C^{12}+He^4\rightarrow O^{16}$. The observed cosmic abundance ratio of He:C:O can be made to fit the yields calculated for these reactions if the reaction $Be^8(\alpha,\gamma)C^{12}$ has a resonance near 0.31 Mev, corresponding to a level at 7.68 Mev in C^{12}.[1] A level had previously been reported at 7.5 Mev.[2] The 16-in. double-focusing magnetic spectrometer has been used in an analysis of the α-spectrum from $N^{14}(d,\alpha)C^{12}$ covering the excitation energy range from 4.4 to 9.2 Mev in C^{12}. The level was found at 7.68 ± 0.03 Mev. No other levels were found, although a group 1 percent as strong as the transition to the 4.4-Mev state could have been detected. At $E_d=620$ kev, $\theta_{lab}=90°$, the transition to the 7.68-Mev state is 6 percent as strong as that to the state at 4.43 Mev.

* Assisted in part by the joint program of the U. S. Office of Nava Research and the U. S. Atomic Energy Commission.
[1] F. Hoyle, to appear in the Astrophys. J.
[2] See F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **24**, 321 (1952).

FRIDAY AFTERNOON AT 4:15

Room 102, Mitchell Hall

(R. F. TASCHEK, presiding)

Contributed Papers

O1. Gamma-ray Absorption Measurements. P. R. HOWLAND, W. E. KREGER, AND R. A. TAYLOR, *U. S. Naval Radiological Defense Laboratory.*—The absorption of gamma-rays in NaI(Tl), Cu, Ta, W, and Hg was measured using a narrow beam geometry and a NaI(Tl) scintillation counter as an energy selective detector. Measurements were made using the gamma rays from Zn^{65}, Cs^{137}, and Co^{60}. Corrections for coherent scattering and small angle Compton scattering were made. Absorption coefficients are compared with theory and results of other workers. Linearity of the scintillation detector system was checked up to counting rates of 300 000 counts per minute, and was found to be better than $\pm\frac{1}{2}$ percent over the range used. An accuracy of $\pm\frac{1}{2}$ percent was obtained for the absorption coefficients. The NaI(Tl) absorption coefficient uncorrected for small angle Compton scattering and coherent scattering was 0.2755 ± 0.0014 cm^{-1} at 0.661 Mev and 0.1991 ± 0.0010 cm^{-1} at 1.11 Mev. Other values will be presented. The work is being continued.

O2. Gamma Radiation from Neutron Excitation of Zirconium and Hafnium. C. W. MALICH AND C. E. FANEUFF, *Naval Research Laboratory.*—The energy spectra of the gamma radiation produced by 14-Mev neutron bombardment of zirconium and of hafnium has been investigated with a NaI(Tl) crystal and multichannel analyzer. The observed counting rates per unit energy interval have maxima near 200 kev and decrease approximately exponentially with increasing energy to 9 or 10 Mev, more rapidly for hafnium than for zirconium. The maxima are due primarily to the 206-kev level in NaI[1] and backscattered gamma rays. Reproducible indications of discrete lines are superposed on the general continua. At low energies these can be ascribed to NaI and to Pb shielding, at intermediate energies they may result from degraded neutrons or $d(d,n)$ contamination, and at high energies are attributed to levels in zirconium or hafnium. An analysis of secondary effects in the detector and scattering by the material investigated is being used to compute cross sections *vs* energy and to identify possible levels.

[1] R. B. Day (private communication).

O3. Long-Lived Activity in Highly Irradiated Niobium. D. L. DOUGLAS, A. C. MEWHERTER, AND R. P. SCHUMAN, *Knolls Atomic Power Laboratory.**—A long-lived activity has been found in two samples of spectrographically pure niobium metal irradiated one and two years, respectively, in the Chalk River reactor. The niobium was purified from tantalum by cellulose column chromatography[1] and by methyldioctylamine extractions.[2] The purified niobium initially contained mainly 35d Nb^{95}; after considerable decay it showed the presence of another activity which followed Nb^{95} when passed through an anion exchange column[3] and in the standard fission-product procedure. The long-lived activity has three gamma rays, 0.70 Mev (92 percent), 0.87 Mev (92 percent), and 1.57 Mev (8 percent), as shown by scintillation spectrometry; also a 0.50-Mev beta ray as shown by Feather analysis. The activity has shown no decay over a period of two months. If the activity is Nb^{94}, its half-life is 2.2×10^4 years, based on a capture cross section of 1.1 barns for Nb^{93}. Also, the Nb^{94} has a capture cross section of about 15 barns based on the specific activity of Nb^{93}.

* Operated by the General Electric Company for the U. S. Atomic Energy Commission.
[1] A. F. Williams, J. Chem. Soc. **1952**, 3155.
[2] G. W. Leddicotte and F. L. Moore, J. Am. Chem. Soc. **74**, 1618 (1952).
[3] K. A. Kraus, G. E. Moore, J. Am. Chem. Soc. **73**, 9 (1951).

O4. Determination of the Neutron Spectrum and Absolute Yield of a Plutonium-Beryllium Source.* LEONA STEWART, *University of California, Los Alamos Scientific Laboratory.*—A plutonium-beryllium neutron source has the advantages of high neutron yield, low gamma-ray intensity, and very long half-life. The neutron spectrum from such a source, composed of 13 grams of plutonium and 7 grams of beryllium as $PuBe_{13}$ (density 3.7 g/cc), was measured by means of proton recoils in nuclear research emulsions with approximately 15° angular resolution. The source and plates were isolated from scattering materials by a Nylon cord suspension. The data obtained from 2114 observations indicate the neutrons have a maximum energy of approximately 10.5 Mev, and the observed spectrum shows marked similarities with published data on

polonium-beryllium[1] and radium-beryllium.[2,3] The present results show intensity maxima at 3.0, 4.4, 7.2, and 9.6 Mev. A comparison is made between the present data and previously reported energy levels in the residual carbon nucleus. The absolute yield of neutrons above 0.5-Mev energy is $9.4\pm1.9\times10^5$ neutrons/sec.

* Work performed under the auspices of the U. S. Atomic Energy Commission. Submitted as a Master's thesis to the University of Texas, January, 1953.
[1] B. G. Whitmore and W. B. Baker, Phys. Rev. **78**, 799 (1950).
[2] H. T. Richards, MDDC-1504 (1944).
[3] D. L. Hill, AECD-1945 (1947).

O5. Cross Sections for Production of In^{115m} and Au^{197m} by Inelastic Scattering of Neutrons. H. C. MARTIN, B. C. DIVEN, AND R. F. TASCHEK, *University of California, Los Alamos Scientific Laboratory.*—Cross sections for the reactions $In^{115}(n, n')In^{115m}$ and $Au^{197}(n, n')Au^{197m}$ have been measured from the reaction thresholds to 5.5 Mev. The lowest mean energy for which the In^{115m} excitation was observed was 440 kev with an energy spread of ±100 kev; the cross section rises to a peak value of 0.36 barn at 2.5 Mev. The lowest mean energy for which the Au^{197m} excitation was observed was 420 kev with an energy spread of ±40 kev; the cross section rises to a peak value of 1.3 barns at 2.5 Mev. Since the $Au^{197}(n, n')Au^{197m}$ reaction threshold gives a maximum value for the excitation energy of the isomeric state, the value obtained is of interest in connection with the decay scheme of Au^{197}.[1] For each reaction, the peak value of the excitation cross section is roughly what might be expected in view of the total inelastic scattering cross section and the spins of the ground state and metastable state.[2] Both cross sections show irregularities which are evidence of energy levels in the target nuclei.

[1] J. W. Mihelich and A. de Shalit (to be published).
[2] B. Margolis (private communication).

O6. The Electron and Positron Spectrum of Zn^{65} above 5 Kev. J. F. PERKINS AND S. K. HAYNES, *Vanderbilt University.*—The electron and positron spectrum of Zn^{65} has been measured with a magnetic lens spectrometer, using very thin sources and counter windows. The positron Fermi plot is found to be linear to 50 kev, in contradiction to certain reports that the positron spectrum was complex. Because of a low-energy tail on the K Auger lines there is a 4 percent uncertainty in the integrated K Auger intensity. From the observed intensities of K Augers, positrons, and conversion electrons, and values of capture branching ratio, fluorescence yield, and L- to K-capture ratios taken from the literature, the intensity ratios of the various spectral components are obtained. The resulting conversion coefficient, $\alpha=(2.56\pm0.29)\times10^{-4}$, agrees with other experimental values and strongly suggests an $E2$ transition. The observed ratio of K capture to ground state to positrons $=28.0\pm3.2$ is in satisfactory agreement with the recently calculated[1] theoretical value of 29.0 for an allowed transition, which in view of the high ft value establishes the l forbidden character of the transition.

[1] P. Zweifel (private communication).

FRIDAY AFTERNOON AT 4:15

Room 122, Mitchell Hall

(L. M. LANGER, presiding)

Contributed Papers

P1. Excitation Functions for the $(n, 2n)$ Reactions in Ge, Sc, As, Tl, and Ni. S. J. BAME, JR.* *University of California, Los Alamos Scientific Laboratory.*—Relative yields as a function of energy for the $(n, 2n)$ reactions in Ge^{70}, Sc^{45}, As^{75}, Tl^{203}, and Ni^{58} have been obtained. The $T(d, n)He^4$ reaction was used as a source of neutrons with energies between 12 and 18 Mev by making use of the angular energy dependence of the reaction. The $(n, 2n)$ products were chemically separated from other activities and counted by the Radio Chemistry group at Los Alamos. Corrections were applied for the laboratory angular distribution of neutrons from the source. The reaction thresholds for As, Tl, and Ni are known from (γ, n) thresholds to be 10.2 ± 0.2, 8.9 ± 0.2, and 11.9 ± 0.2 Mev. The data agree well with these values. Threshold values for Ge and Sc are 11.8 ± 0.3 Mev and 11.3 ± 0.3 Mev, determined from the $(n, 2n)$ data. The yield curves have the same general shape, rising from the threshold to a maximum value, then falling smoothly to around 70 percent of the maximum at 18 Mev. The energies at which the maximum yields occur are approximately 14.8, 15.3, 15.9, 16.2, and 16.2 Mev for Tl, As, Sc, Ge, and Ni.

* Work done under the auspices of the U. S. Atomic Energy Commission.

P2. Isotopic Abundances of Palladium. JOHN R. SITES, GEORGE CONSOLAZIO,* AND RUSSELL BALDOCK, *Stable Isotope Research and Production Division, Oak Ridge National Laboratory.*†—In the course of investigating calutron separated isotopes of palladium, a difference from the published isotopic abundance values for natural palladium was observed. The new values to be reported in atom percent are Pd^{102}, 0.96; Pd^{104}, 10.97; Pd^{105}, 22.23; Pd^{106}, 27.33; Pd^{108}, 26.71; and Pd^{110}, 11.81.

* Watertown Arsenal, Watertown Massachusetts.
† This paper is based on work performed for the U. S. Atomic Energy Commission by Carbide and Carbon Chemicals Company, a Division of Union Carbide and Carbon Corporation, at the Oak Ridge National Laboratory.

P3. Electromagnetic Separation of Pd, Pt, and Ru Isotopes. W. A. BELL, JR., L. O. LOVE, C. E. NORMAND, AND W. K. PRATER, *Stable Isotope Research and Production Division, Oak Ridge National Laboratory.**—Appreciable quantities of the isotopes of Pd, Pt, and Ru have been electromagnetically separated in high-temperature source units. Ion beams up to 30 ma at the isotope collector were achieved. Bombardment of graphite charge containers by 35-kv electrons produced the temperature, in excess of 2000°C, required to vaporize sufficient metallic charge to support the ionization arc. The heat shielding problem and its solution are discussed.

* This paper is based on work performed for the U. S. Atomic Energy Commission by Carbide and Carbon Chemicals Company, a Division of Union Carbide and Carbon Corporation, at the Oak Ridge National Laboratory.

P4. The Spin and Magnetic Moment of Ti^{47} and Ti^{49}. C. D. JEFFRIES, *University of California, Berkeley.*—The complex nuclear induction signal from $TiCl_4$ previously reported[1] has been re-examined under higher resolution. It is found that the structure is actually a superposition of two resonance lines with a relative separation of about one part in 3800. By the

use of Oak Ridge separated isotopes the resonance lines have been identified as those of Ti^{47} and Ti^{49}. The ratio of the resonance frequency of these nuclei to that of Cl^{35} in $TiCl_4$ has been measured to be $\nu(Ti^{47})/\nu(Cl^{35})=0.57493\pm0.00006$, and $\nu(Ti^{49})/\nu(Cl^{35})=0.57508\pm0.00006$. By comparing the widths and amplitudes of the two Ti signals, their spins have observed to be $I(Ti^{47})=5/2$ and $I(Ti^{49})=7.2$. Both Ti resonance signals are negative with respect to that of Cl^{35}, indicating that the magnetic moments are negative. The magnetic moments are found to be, in units of the nuclear magneton, $\mu(Ti^{47})=-0.7866$, and $\mu(Ti^{49})=-1.102$. These values are in agreement with those predicted by the scheme of Schawlow and Townes.[2]

[1] Jeffries, Loeliger, and Staub, Phys. Rev. **85**, 478 (1952).
[2] A. L. Schawlow and C. H. Townes, Phys. Rev. **82**, 268 (1951). The calculated value for $\mu(Ti^{47})$ is in error and should be -0.80 (private communication).

P5. Angular Distribution of Neutrons from $O^{18}(p, n)F^{18}$.† HANS MARK AND CLARK GOODMAN, *M.I.T.*—The reaction $O^{18}(p, n)F^{18}$ was studied using monoenergetic protons from the Rockefeller electrostatic generator. The targets were made by oxidizing tantalum disks in enriched (20 percent O^{18}) oxygen which was obtained from Professor Alfred O. Nier. It was possible to obtain a surface layer of $Ta_2O_5^{18}$ which was roughly 20 kev thick for 3-Mev protons. The neutron yield in the forward direction was measured using a long counter.[1] Resonances were observed at proton energies $E_p=2.657$, 2.778, 3.050, 3.170, 3.268, 3.385, 3.494 Mev in agreement with Richards *et al.*[2] Additional resonances were observed at $E_p=2.732$, 3.665, 3.756 Mev. The angular distribution of neutrons at several energies was measured using a proton recoil counter.[3] The most probable spin and parity assignments for the various excited states have been made. The results seem to indicate that in the energy range $E_p=3.0$ to 3.5 the resonance structure is not simple but that there exists a broad state upon which the sharp resonances are superposed.

† Work jointly supported by the U. S. Office of Naval Research and the U. S. Bureau of Ships.
[1] Roseborough, McCue, Preston, and Goodman, Phys. Rev. **83**, 1133 (1951).
[2] Richards, Smith, and Browne, Phys. Rev. **80**, 524 (1950).
[3] Kay, Mark, and Goodman, Phys. Rev. (to be published).

P6. The Scattering of Fast Neutrons by Iron, Lead, and Chromium.* M. A. ROTHMAN, D. W. KENT, AND C. E. MANDEVILLE, *Bartol Research Foundation of the Franklin Institute.*—Fast neutrons of 3.7-Mev energy have been inelastically scattered in Fe, Pb, and Cr. Using a NaI—Tl crystal, a photomultiplier, and pulse-height selection, gamma rays are detected from iron at 0.88 Mev, from lead at 2.65 Mev, and from chromium at 1.43 Mev. The neutron energy spectrum obtained, using 4.2-Mev incident neutrons, a chromium scatterer, and photographic emulsion detection, shows two unresolved groups: the elastic group and another, inelastic, corresponding to a Q of about -1.4 Mev.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

P7. Angular Distribution of Neutrons Scattered from Aluminum, Iron, and Lead.* W. D. WHITEHEAD AND S. C. SNOWDON, *Bartol Research Foundation of the Franklin Institute.*—The differential cross sections for the scattering of 3.7-Mev neutrons by Al, Fe, and Pb have been measured between 13° and 140° with an angular resolution of ±10 degrees. The measurements were performed in a ring geometry in which the angle variation was accomplished by an axial movement of the ring. Corrections for the higher-order scattering have been determined experimentally by varying the thickness of the scatterer and extrapolating to zero thickness. Since the energy response of the neutron detector (Zn—sLucite button mounted on a photomultiplier) does not permit complete discrimination against the low-energy neutrons, the differential cross sections are not the elastic cross sections. However, a crude estimate indicates that the low-energy neutrons do not contribute more than 20 percent to the measured differential cross sections. The cross sections exhibit strong maxima in the forward direction. Iron and lead have secondary maxima at 110° and 90°, respectively. The total cross sections were also measured at 3.7 Mev by a standard transmission experiment giving 2.55, 3.51, and 7.60 barns for Al, Fe, and Pb, respectively, in good agreement with the values of Nereson and Darden.[1] The difference between the total cross section and integral of our differential cross section gives a measure of the total inelastic cross-section.

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
[1] N. Nereson and S. Darden, Phys. Rev. **89**, 775 (1953).

FRIDAY EVENING AT 7:00

Hilton Hotel

(J. KAPLAN, presiding)

Banquet of the American Physical Society

After-dinner speaker: A. T. WATERMAN

SATURDAY

Excursions (to be announced)

SUPPLEMENTARY PROGRAMME

SP1. Structure and Resistivities of Gold Films Deposited by Evaporation and Sputtering.*† RICHARD B. BELSER, *Georgia Institute of Technology.*—Gold films of 1000 angstrom's thickness, deposited on glass microscope slides by normal evaporation procedures at about 10^{-5} mm of Hg pressure, have been found to have an initial resistivity of approximately $2\rho_b$. These films change in resistance slowly at room temperature and may drop 15 percent in two weeks. When heated to 250–300°C, they drop further in resistivity to a value approximately 65 percent of the initial value of $1.3\rho_b$. Heating to higher temperatures, about 450°C, may cause the film to aggregate resulting in a high or unmeasurable resistivity. Sputtered gold films, on the other hand, have an initial resistivity dependent on the sputtering rate. At a nominal high sputtering rate, 40–50 ma, the resistivity will be approximately $4.5\rho_b$. Such films do not change in resistance with room temperature. Heating to 300°–400°C causes a considerable reduction in resistivity to values in the range 1.5–$2.0\rho_b$. In some instances, and at high sputtering rates, even higher temperatures appear necessary to produce a reduction to the minimum resistivity. The greater resistance of these films to aging at room or elevated temperatures appears to be related to occluded gas and lattice imperfections produced by bombardment during the severe sputtering action.

* To be given at the end of Session C if the chairman rules that time permits.

† Supported by U. S. Army Signal Corps.

SP2. Indium, a Versatile Solder to Metals and Nonmetals.*† RICHARD B. BELSER, *Georgia Institute of Technology.*—Indium is a soft silvery metal of 155°C melting point. In the molten state it adheres to many metals and nonmetals and continues to adhere upon solidification. This dual ability makes it a valuable laboratory and industrial material. Some adherence has been obtained with indium to twenty-four metals and 18 nonmetals. The metals tested include most common industrial metals, and the nonmetals include glass, ceramics, quartz, mica, metallic oxides, and silicious minerals. A flux is useful in soldering to metals near or below indium in the electrochemical series, but fluxes are not useful for soldering to the active metals or to nonmetals. Fluxes appear to inhibit wetting of these materials. A number of indium-rich alloy solders were tested for strengths and melting points. Alloys with small percentages of silver and larger percentages of lead and tin appear useful. These solders have been found valuable for mechanical suspension, electrical connections, soldering to thin metal films, mounting piezoelectric crystals, and glass to metal vacuum seals.

* To be given at the end of Session C if the chairman rules that time permits.

† Supported by U. S. Army Signal Corps.

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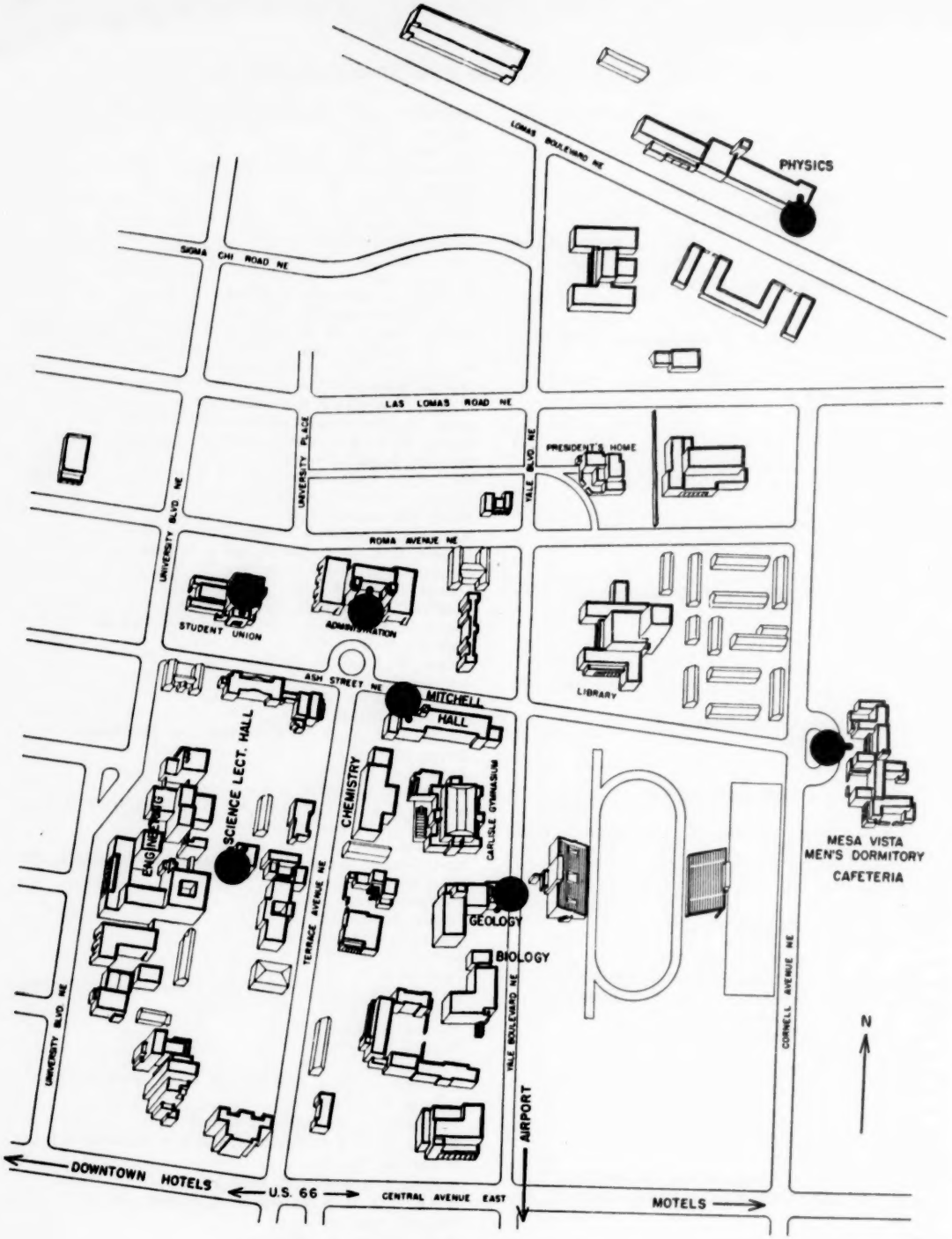

CAMPUS OF THE UNIVERSITY OF NEW MEXICO

The American Physical Society

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Please cut along this line

(To be sent to Dr. Victor H. Regener, University of New Mexico, Albuquerque, New Mexico)

I EXPECT to attend the dinner of the American Physical Society at seven o'clock on Friday evening, September 4. My party will comprise ..... persons.

(*Name*).....

(*Address*).....